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ELECTRIC LIFTS

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A Practical Treatise on their Construction, Operation and Maintenance

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# ELECTRIC LIFTS

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# ELECTRIC LIFTS

# ELECTRIC LIFTS

A Practical Treatise on their Construction Operation and Maintenance

BY
"CONTACTOR"

GENERAL EDITOR
E. MOLLOY,
Editor of *Electrical Engineer*

WITH 97 DIAGRAMS AND PHOTOGRAPHS

LONDON
GEORGE NEWNES LIMITED
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## PREFACE

DURING the past ten years electric lifts have assumed a steadily increasing importance. Practically every modern block of flats or business premises may contain anything from five to twenty storeys. It is no exaggeration to say that buildings of this height would be out of the question were it not for the fact that lifts can be provided to provide rapid and effortless vertical travel for the people using these buildings.

Owing to the fact that electric power is now available in practically every building of this type, by far the greater number of lifts now being installed are electrically operated.

Although the number of electric lifts has increased out of all knowledge during the past few years, the amount of technical information available on this subject has been exceedingly meagre. The main object of the present book is to supply the present-day need for a clearly written practical work, which will be useful not only to the consulting engineer and contractor who may have occasion to specify or install electric lifts, but also to the maintenance engineer who is responsible for keeping these lifts in effective service.

The first chapter contains a survey of present-day types and layout arrangements. The basic principles governing the height, speed and power requirements of different types of lifts are clearly outlined. The points touched upon in this chapter serve to emphasise a fact which is well-known to all lift engineers of experience, namely that the design, construction and operation of lifts is a study involving not only electrical principles, but also many interesting problems of mechanical engineering and

acoustics and the laws of probability. In addition account must be taken of the human factor. The conditions to be fulfilled in offices, hotels and hospitals, for example, are entirely different in each case and it is only by a careful study of the requirements of each that the most suitable type of lift can be decided upon.

After this thorough introduction to the subject the succeeding chapters are devoted to the mechanical and electrical details of the lift operating and control mechanism. Two chapters of particular interest in this connection are Chapter IV, which deals with auxiliary and lift well equipment and Chapter V, which deals with signalling equipment. The concluding chapter is devoted to routine maintenance and the diagnosing of faults, together with their appropriate remedies.

We have pleasure in expressing our indebtedness to the leading lift manufacturers for having assisted us by supplying illustrations showing some of the most modern types of lift equipment.

"CONTACTOR"
E. M.

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# ELECTRIC LIFTS

## CHAPTER I

## EQUIPMENT AND LAYOUT ARRANGEMENTS

DETAILS of design and arrangement of modern electric lifts vary widely, but the fundamental principles which govern their design and operation remain unaltered. It is these principles and their general application in practice that form the chief subject-matter of the present book.

Before describing the general types and layouts of various lifts it will be advantageous to give a brief description of the main components of the present-day lifts at this stage and to explain in detail later.

### LIFT EQUIPMENT

**The Drum-type Machine.**

The drum type of machine is now used only for special applications; the diameter and length of the drum are determined by the speed of the lift car and the length of travel, and with the increasing height of modern buildings the size of the drum becomes prohibitive.

**The Traction-type Machine.**

To overcome this difficulty the traction type of machine was developed, and once the sheave diameter has been determined for a given car speed it can be

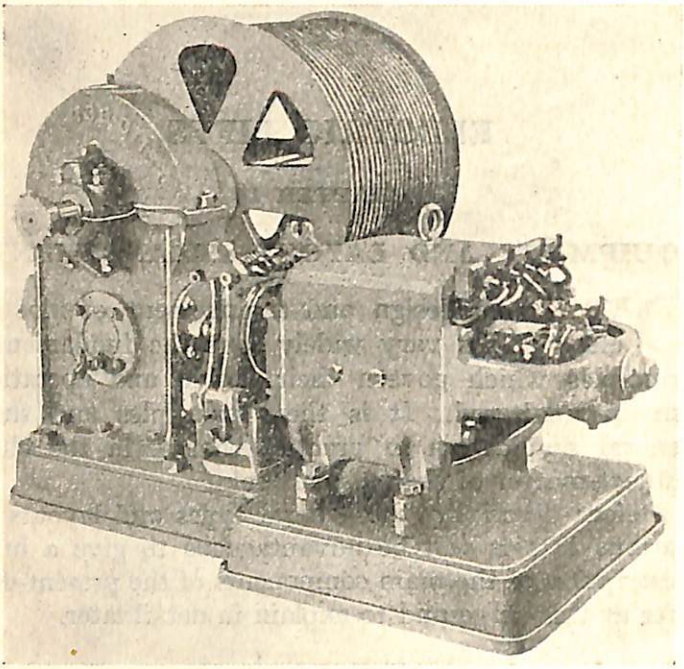


FIG. 1.—THE DRUM-TYPE OF MACHINE.

This type of machine is now used only for special applications. Two sets of ropes are necessary, one end of each set being anchored to the drum and the other ends being attached to the car and counterweight respectively. With increasing height of modern buildings, size of drum becomes prohibitive.

employed for any rise. With the drum type of machine two sets of ropes are necessary, one end of each set being anchored to the drum and the other ends attached to the car and counterweight respectively. As the car ropes wind on to the drum to raise the car the counterweight ropes unwind from it, and it is therefore necessary for the length of one set of ropes, equal to the car rise, to be wound on the drum.

Only one set of ropes is required for a traction machine, the ropes, being fixed to the car, passing over the traction sheave to their anchorage on the counterweight, and the friction between the sheave and ropes is employed to transmit the necessary effort to raise the load.

It will be noticed that whilst the traction machine is generally similar to the drum machine it occupies less floor space, especially on a long-travel lift, owing to the substitution of the sheave for the drum.

**The Geared Traction-type Machine.**

A geared traction machine consists of a motor, electro-mechanical brake, worm reduction gearing, and sheave mounted on a common bedplate. The geared traction machine is now installed for car speeds of up to 350 ft. per min., and for car speeds of 350 ft. per min. and over, the gearless type-traction machine is used.

**The Gearless Traction-type Machine.**

As its name implies, the gearless machine has no form of reduction gearing, the sheave and brake drum being mounted direct on the shaft of a slow-speed motor. With gearless machines, motor-generator sets are now invariably employed to provide a variable voltage with which to control the speed of the machine.

A lift installation employing a gearless machine with variable-voltage control, is relatively expensive, but it represents the highest class of lift engineering and affords smoothness in acceleration, retardation, and running over very long periods without attention, and wear is negligible.

**Types of Sheave Grooving.**

As previously mentioned, the friction between the ropes and the sheave of a traction machine is utilised to transmit the effort required to accelerate and raise the load, and the sheaves are provided with grooves to accommodate the ropes. The form of these grooves is important, and it varies from a V to a U form, according to several factors which will be discussed later. At this juncture, however, it will suffice to state that it is usual for geared traction machines to have V or half-round undercut grooves and for gearless machines to have U grooves. It will be appreciated that with U-shaped grooves there is no wedging effect between the rope and groove, and whilst this improves the life of the rope the tractive effort is reduced, and to overcome this disadvantage a secondary sheave is employed.

**Types of Traction Drive.**

The secondary sheave is usually somewhat smaller in diameter than the traction sheave and is mounted substantially beneath it; the ropes from the car pass over the traction sheave, round the secondary sheave, over the traction sheave again, and then to the counterweight. Because the ropes pass over the traction sheave twice this arrangement is known as *double wrap*, and it is necessary for the traction and secondary sheaves to have twice as many grooves as there are ropes. The ropes on a geared machine pass once over the sheave and make an arc of contact of approximately 180° with the sheave, and this arrangement is known as *single wrap*, but with double wrap an arc of contact approaching 360° is attained.

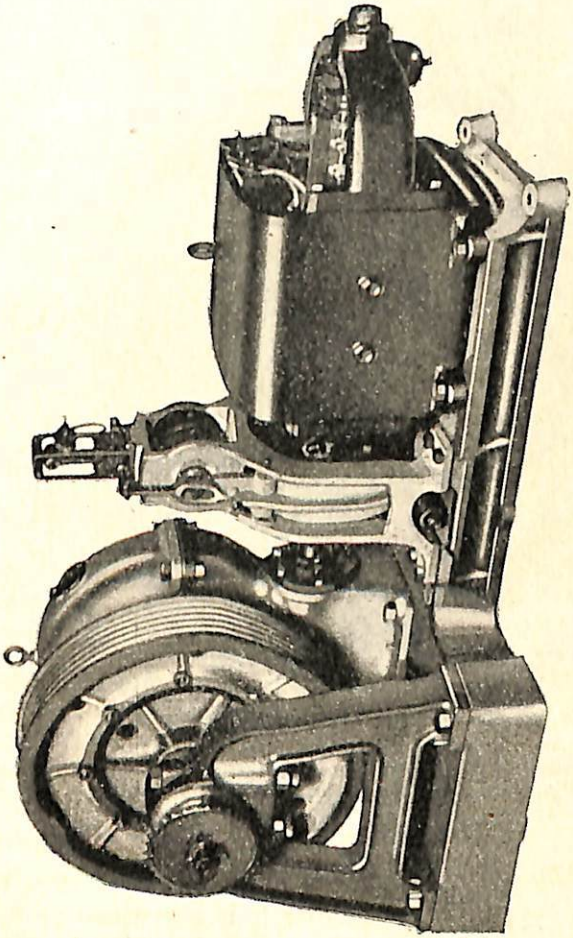


FIG. 2.—THE TRACTION-TYPE LIFT MACHINE.

Only one set of ropes is required. The ropes are fixed to lift car; they pass over traction sheave and are anchored to counterweight. Friction between sheave and ropes transmits necessary effort to raise the car.

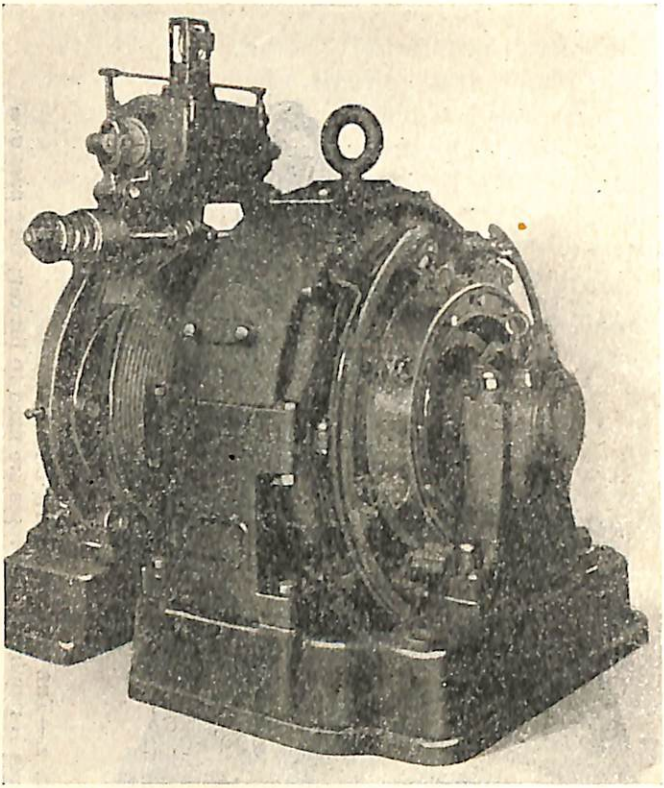


FIG. 3.—GEARLESS TRACTION-TYPE MACHINE.

Sheave and brake drum are mounted direct on shaft of slow-speed motor. Motor-generator set is usually employed to provide variable voltage with which to control speed. See Fig. 4.

**Controllers.**

For all types of electric lifts it is necessary to have a controller which, in conjunction with the car switch or operating buttons, controls the starting, acceleration, retardation, stopping, and direction of rotation of the

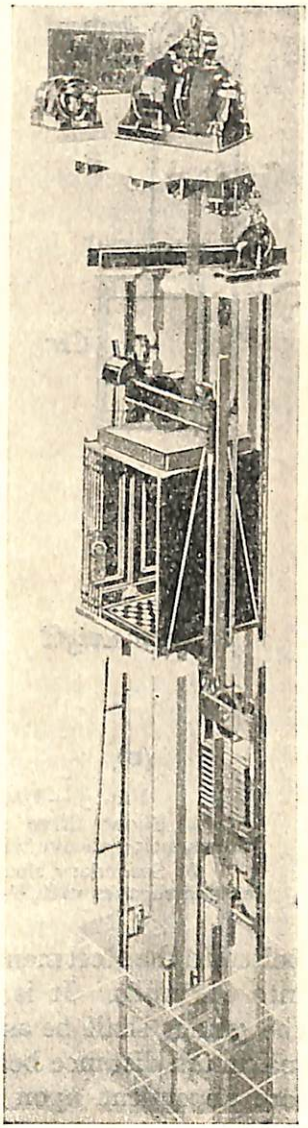


FIG. 4.—LIFT INSTALLATION, USING GEARLESS MACHINE.
Note motor-generator set giving variable voltage control.

motor. With some automatically operated lifts the stopping of the car is accomplished by means of mechanically driven limit switches, which may be mounted on the main controller or alternatively arranged as a separate unit. The controller is usually fixed to the machine-room floor conveniently situated with respect to the machine.

**Guides.**

The car and counterweight are guided in their travel by means of rigid steel guides, which for light-duty lifts are of round section and for heavier duties are of T-section. Whichever form of section is used it is necessary to provide a male and female joint between each section to ensure rigidity. The guides are secured to the sides of the lift well by means of steel fixings, which are either

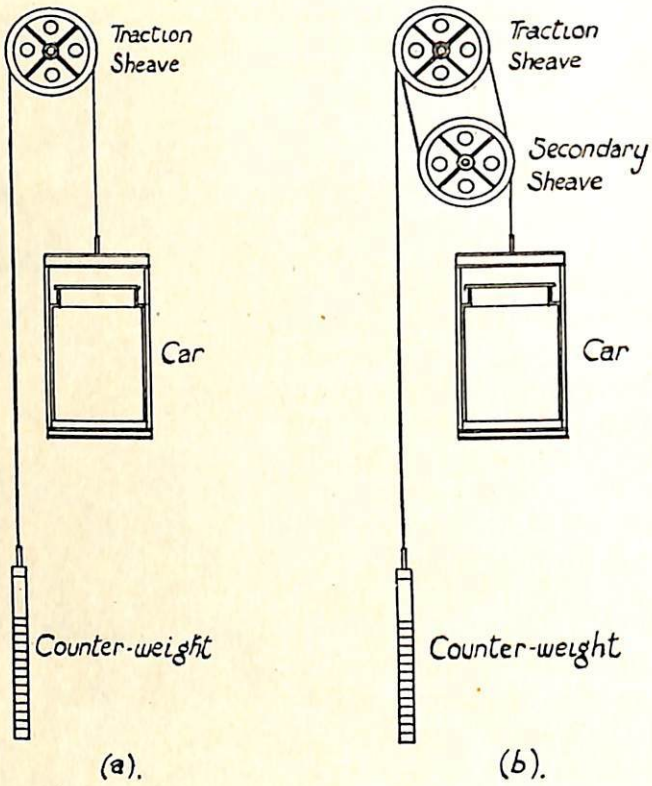



FIG. 5.—TYPES OF TRACTION DRIVE.
(*a*) Shows drive employed for geared traction machines, using sheave with V-shaped groove.
(*b*) Secondary sheave is used with gearless machines having sheaves with U-shaped grooves.

bolted to the steel members of the building or cemented into the walls. It is essential that the deflection of the guides shall be as small as practicable, and the maximum distance between the guide fixings is therefore dependent upon the modulus of section of the

guide, the duty of the lift, the size of the car, and type of safety mechanism fitted to the car.

**Counterweights.**

Except in most exceptional instances, lifts are provided with counterweights, which consist of a number of cast-iron sections suitably carried to form a single unit, and the weight of the counterweight is equal to the weight of the car plus from 40 per cent. to 50 per cent. of the maximum load carried in the car. By using a counterweight not only is the size of the machine reduced considerably but the rate of acceleration and retardation is more constant and general running performance improved.

**Car Frames, Safeties, and Governors.**

The car, whether for goods or passenger service, should be carried in a continuous steel frame incorporating the car-safety mechanism. It may be pointed out that the type of car-safety depends upon the car speed, and whilst it is now becoming common practice to furnish overspeed governors for all but light-duty lifts, instantaneous operating safeties are used for car speeds of up to 200 ft. per min. and gradually operated safeties for higher speeds. The car-safety is designed to hold the car to the guides in the event of the car speed becoming excessive in the down direction or in the unlikely event of the lifting ropes failing. When safeties are arranged to operate with excessive speed, a governor is fitted in the machine-room, the car-safety being operated by a releasing device attached to the endless governor rope, which is held taut by a tension device accommodated in the lift pit.

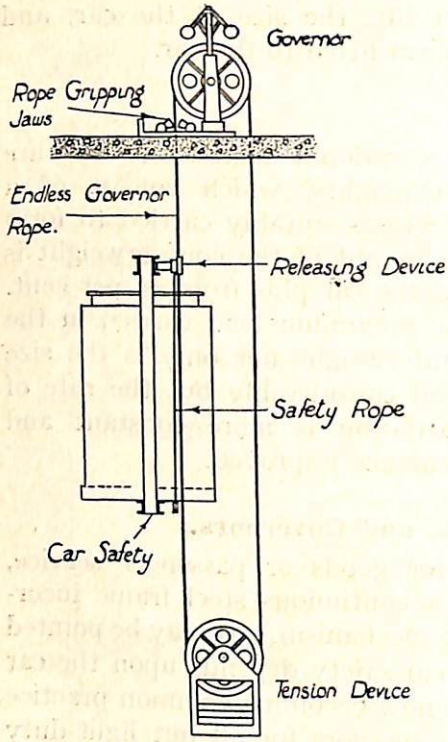



FIG. 6.—TYPICAL ARRANGEMENT OF CAR SAFETY FOR OPERATING AT EXCESSIVE SPEED.

Car safety is operated by releasing device attached to governor rope.

**Buffers.**

With geared traction machines spring buffers are installed in the pit to absorb the energy stored in the car or counterweight should either of these pass the normal limits of travel, but with gearless machines, owing to the higher car speed, hydraulic buffers are used in place of spring buffers.

**Rope Compensation.**

It will be appreciated that with the increasing height of buildings the weight of the lifting ropes becomes an important item; when the car is ascending from the lowest landing the machine has to raise not only the car and its load but also the ropes, and it is usual to employ means for compensating the weight of the ropes for car rises of about 100 ft. or over. Rope compensation for moderate car speeds is usually

achieved by connecting one or more chains from the under side of the car frame to the counterweight, the length of chain being such that it clears any equipment in the pit. For high car speeds, or where the expense is justified, ropes are substituted for the chains, and tension is maintained in these ropes by means of a tension frame and pulley suitably guided and installed in the pit.

**Methods of Roping.**

Whilst the speed of a lift is primarily dependent upon the motor speed, the gear ratio, and diameter of the driving sheave, it is possible to halve the speed and double the lifting capacity of a given machine by employing 2 : 1 roping. For this arrangement of roping it is necessary to equip the car frame and the counterweight with a pulley for the lifting ropes to pass under and to fix the ends of the ropes at the top of the lift well, as shown in Fig. 8. This method of roping is particularly useful for goods lifts where heavy loads are to be handled and the sacrifice of speed is of little importance; another application is for the lower car speeds of gearless machines. If a load of 2,000 lb. is to be raised at a speed of 350 ft. per min. by a gearless machine, the diameter of ropes and sheave would be $\frac{1}{2}$ in. and 30 in. respectively, and the speed of the motor with 2 : 1 roping would be $89\frac{1}{2}$ r.p.m.; if, however, the roping were 1:1, the motor speed would have to be $44\frac{3}{4}$ r.p.m.

The output of a motor for the duty just cited would be 17 h.p., and to maintain this output at half the speed would necessitate doubling the torque, which would necessitate a larger size motor frame. It will

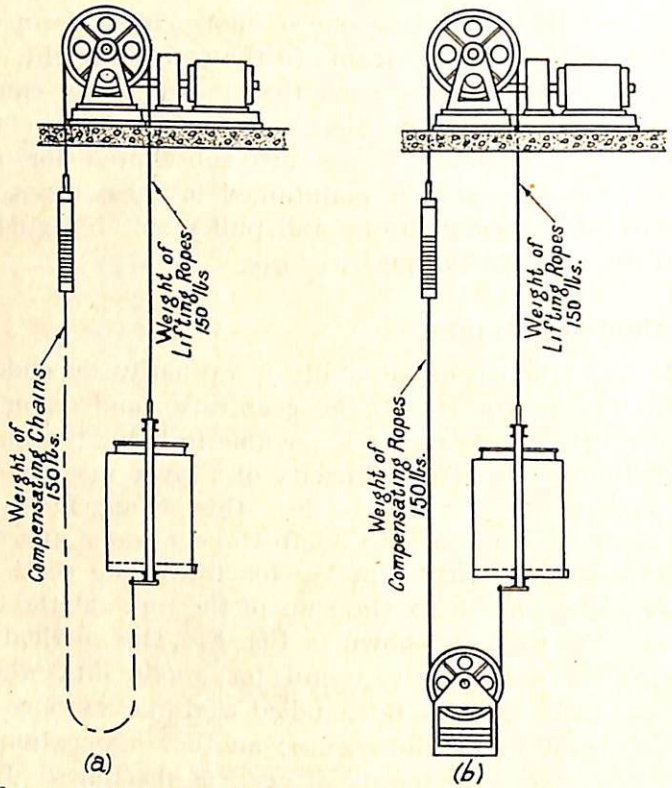

Weight of Lifting Ropes 150 lbs.
Weight of Compensating Chains 150 lbs.
(a)
Weight of Lifting Ropes 150 lbs.
Weight of Compensating Ropes 150 lbs.
(b)

FIG. 7.—METHODS OF BALANCING WEIGHT OF ROPES FOR CAR RISES OF 100 FT. OR OVER.
(*a*) Shows use of a compensating chain and (*b*) use of compensating ropes where expense is justified.

therefore be appreciated that the use of 2:1 roping with the lower car speeds of gearless installations enables a less expensive machine for a given duty to be employed.

**Special Counterweight Arrangement.**

Unusual site conditions may be such that the

counterweight cannot travel the same distance as the car and it is therefore necessary to furnish 2 : 1 roping for the counterweight, and with such an arrangement the weight of the counterweight must be made twice as great as it would be if the roping were 1 : 1, where it will be observed that the pull in the counterweight ropes and the load on the machine sheave are the same as that for the 1 : 1 roping arrangement shown in Fig. 8 (*a*).

**Some Useful Calculations.**

The position of the machine has an important effect upon the loads imposed by the lift upon the building. Assume that a load of 3,000 lb. is to be raised at a speed of 200 ft. per min., the weight of the machine and controller may be taken as 4,000 lb. and that of the car as 3,500 lb., making the weight of the counterweight 4,700 lb. Referring to Fig. 10, it will be observed that, with the machine below, the load on the building is considerably more than with the machine above, although, in the former case, the weight of the machine and controller is not imposed upon the structure of the building. This increase in loading is due to the pull in the ropes leading from the machine, and the pull in these ropes must of necessity be equal to the weight of the loaded car and counterweight respectively. It may be mentioned in passing that the size of the joists for carrying the machine or pulleys is calculated for an equivalent dead load of twice the pull in the car and counterweight ropes plus the weight of the machine or pulleys, so the equivalent dead load for the machine-above condition, as shown in Fig. 10 (*a*), is

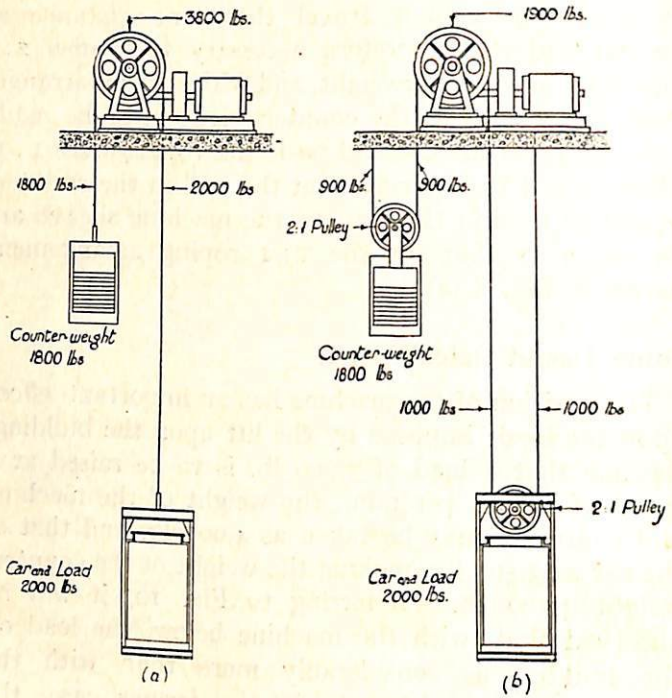



FIG. 8.—METHODS OF ROPING.
The use of 2 : 1 roping is shown at (*b*).

$$2(6{,}500 + 4{,}700) + 4{,}000 = 26{,}400 \text{ lb.}$$

and for the machine-below condition, Fig. 10 (*b*), the equivalent dead load (e.d.l.) is—

$$2 \times 2(6{,}500 + 4{,}700) + 500 = 45{,}300 \text{ lb.}$$

Whilst on the subject of loading, it may be of interest to point out that the load on the sheave shaft of a machine is doubled when a secondary sheave is employed; reference to Fig. 11 will show the reason for this increased loading. With 2 : 1 roping, however, the load on the sheave shaft is halved, because half

the load is taken on the building, and it therefore follows that, for given conditions, the sheave-shaft load of a lift roped 2 : 1 with double-wrap roping is the same as that of a lift roped 1 : 1 with single-wrap roping.

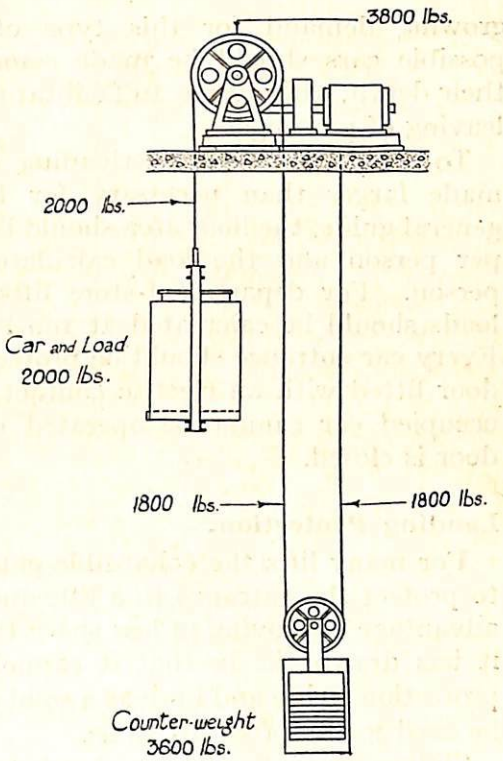



FIG. 9.—SPECIAL COUNTERWEIGHT ARRANGEMENT WHERE COUNTERWEIGHT CANNOT TRAVEL SAME DISTANCE AS CAR OWING TO SITE CONDITIONS.
Compare with Fig. 8 (*a*).

**Cars.**

Cars take many forms. For goods service they are constructed of mild-steel angles fitted with timber boarding or alternatively of sheet steel suitably reinforced. The latter is gradually superseding the former, except where certain processes demand timber. For passenger service the design as well as the material varies widely; some are made in timber and veneered, others in bronze or cellulosed steel. Owing to the many possibilities of colour schemes with cellulose spraying there is a

growing demand for this type of car. Wherever possible cars should be made somewhat wider than their depth, with a view to facilitating the entering and leaving of passengers.

To avoid the risk of overloading, cars should not be made larger than necessary for their duty. As a general guide, the floor area should be based on 2 sq. ft. per person and the load calculated at 150 lb. per person. For department-store lifts and the like the loads should be calculated at 100 lb. per square foot. Every car entrance should be protected with a gate or door fitted with an electric contact to ensure that an occupied car cannot be operated unless the gate or door is closed.

**Landing Protection.**

For many lifts the collapsible gate is still employed to protect the entrance to a lift, and whilst it has the advantage of moving in less space than a hinged door, it has drawbacks in that it cannot afford the same protection to life and limb as a solid door and it cannot be used for fireproof lift wells.

Sliding doors have been developed with a view to retaining the advantages of collapsible gates. Such doors can be arranged for manual opening and automatic closing or for automatic opening and closing by means of an electric motor with suitable gearing (see later).

**Locks.**

The landing doors and gates of all electric lifts are provided with locking devices which will ensure that the doors or gates cannot be opened unless the car is

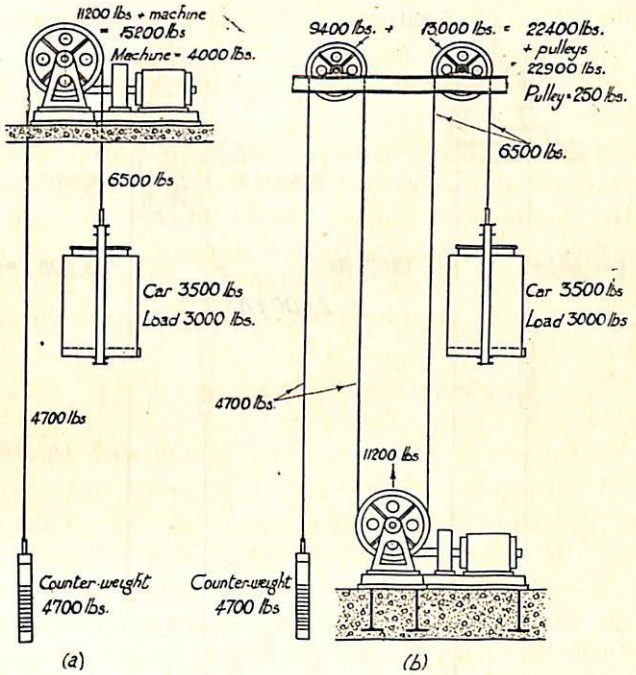



FIG. 10.—POSITION OF MACHINE.

With machine below lift as at (*b*), load imposed by lift on the building is considerably more than with machine above (*a*).

opposite to it, and that the lift cannot be operated unless all gates or doors are fully closed. Such locking devices are usually equipped with a roller and lever, which engages with a cam on the car when the car is standing at a floor, thus enabling the lock to be released and the door opened. By arranging the cam on the car to be withdrawn from the plane of the roller levers on the locks by means of a solenoid, or the like, whilst the car is in motion, a landing door

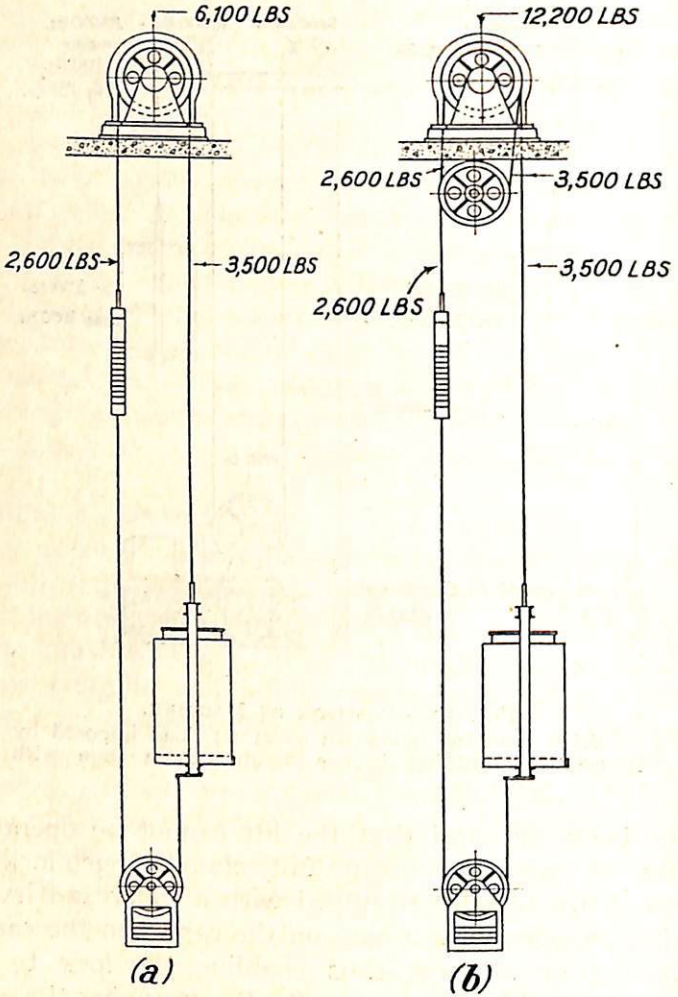



FIG. 11.—LOAD ON SHEAVE SHAFT.

Load on sheave shaft of machine is doubled when secondary sheave is employed (*b*). With 2 : 1 roping, however (see Fig. 8 (*b*), the load on sheave shaft is halved, because half load is taken on building.

cannot be opened until the car has stopped at a floor. This device, known as a retiring cam, prevents the door or gates from being snatched open as the car passes a landing.

With manually opened sliding doors on attendant-operated lifts it is usual to incorporate the locking of the door in the automatic closing mechanism, which is so arranged that the operating levers form a straight line when the door is closed and so prevent them from being opened from the landing side.

## LAYOUT ARRANGEMENTS.

### An Ideal Layout.

From the foregoing outline of lift equipment it will be appreciated that many arrangements of lift layouts are possible, each arrangement having its own peculiarities depending upon site conditions, type of lift, its method of control, and its duty. The ideal layout is with the machine situated direct over the lift well with all entrances to the lift on one side of the lift well.

All machine-rooms should be made large enough to give easy access to the machinery for cleaning and adjusting; to save floor space by cramping a machine-room is false economy.

Where a car is open at its back and front the distance between the rope anchorages of the car and counterweight is usually too great for a spanning sheave, and it is therefore necessary to provide a diverting pulley in order that the ropes will lead plumb to their anchorages. It may be thought that a diverting pulley could be avoided by making the sheave large enough to span and to increase the gear ratio or lower the motor speed

to compensate for the increase of sheave diameter, but such a step may lead to a very short life of the worm-gear members due to the increased pressure between the worm and wheel; to use a slow-speed motor would entail more expense than providing a diverting pulley.

**Use of Self-supporting Steel Structure.**

At times lifts have to be installed in existing buildings where it is not possible to carry the loads due to the lift on the walls of the building, and in such instances a self-supporting steel structure is used. Such structures are carried on concrete foundations with the guides for the car and counterweight, and also the necessary steel joists for supporting the machine, fixed to the structure. The sides of the structure may be enclosed with substantial wire-mesh panels or with breeze slabs plastered and decorated.

**Cases where Machines are Installed at Bottom of Lift Well.**

Whilst it is advantageous for the machine to be arranged direct over the lift well, conditions are sometimes met which compel the machine to be installed at the bottom and adjacent to the lift well. When a machine is installed below it is necessary to furnish two or more pulleys with the necessary steel-work at the top of the lift well for leading the ropes down to the car and counterweight.

An arrangement with the machine below having its sheave directly under the lift well is illustrated in Fig. 15. This layout is particularly useful when the lowest floor served is above the machine-room. In

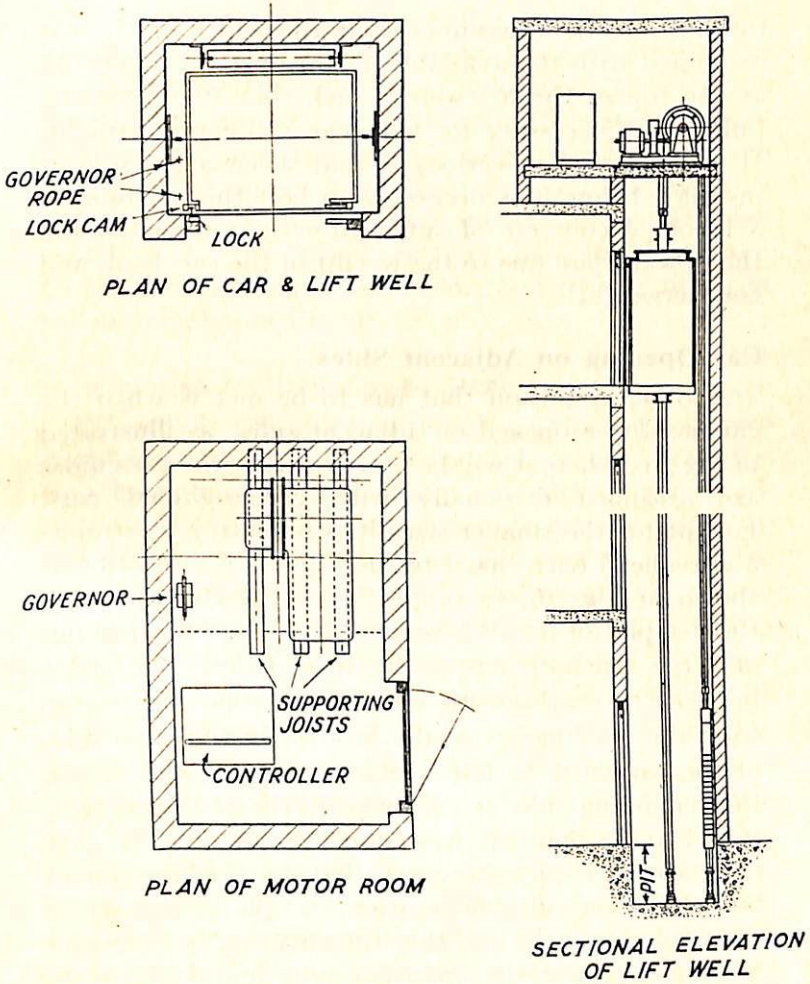



FIG. 12.—AN IDEAL LIFT LAYOUT.

With the machine situated directly over the lift well and all entrances to the lift placed on one side of the well. Arrangement shown is for load of 1,000 lb. and speed 100 ft. per min. It will be noticed that the steel joists carrying the machine are supported by the brickwork which forms the lift well.

this instance it is assumed that the width of the car combined with the available height over the steelwork at the top of the lift well is such that two diverting pulleys are necessary for both car and counterweight. It should not be overlooked that when a machine is installed below it is necessary to bolt the machine to a block of concrete of sufficient weight to withstand the upward pull due to the weight of the car, load, and counterweight.

**Car Opening on Adjacent Sides.**

Another condition that has to be met is when the car has to be opened on adjacent sides, as illustrated in Fig. 16, where it will be observed that the car guides are arranged diagonally with corner-guided cars. Except for the smaller sizes it is necessary to arrange a cross-head truss, fixed to the top of the car frame as shown in Fig. 16, to support the opposite corners of the car platform. When a car has adjacent openings and the machine has to be fixed below, the space between the car and lift well for the ropes to pass up from the machine is usually limited, in that two sides of the car must be left free for entrances and one of the remaining sides is occupied by the counterweight, thus leaving one side free for the ropes. Site conditions are often such, however, that the machine cannot be fitted in a suitable position to take advantage of the remaining side, and this difficulty can be overcome by side-stepping the counterweight and leading the ropes up the lift well as shown in Fig. 16.

**Layout of Lift Employing Gearless Machine.**

The layout of a lift employing a gearless machine

with variable-voltage control (Fig. 17) does not differ greatly from that of a geared machine, but provision must be made for additional equipment such as the motor-generator set, motor-generator starter, secondary sheave, and at times a floor selector. Referring to Fig. 4, which shows a gearless-machine installation, it will be noticed that the car and counterweight are roped 2 : 1, the counterweight has its hydraulic buffer attached to its under side, and the car buffer is accommodated in the pit.

**Special Use for Drum-type Machine.**

When it is necessary to raise a platform to a level such as a loading bank, street-level, or say, the floor in a main banking hall, where any form of overhead support is impracticable, advantage can be taken of the drum-type machine. The platform, as shown in Fig. 18, is provided with an undercarriage, which accommodates two pulleys and also the guide shoes, which are spaced as far apart as convenient to ensure proper guiding. One end of each rope is attached to a suitable support under the floor and the other ends are attached to the winding drum, after passing over a pulley also fixed immediately under the floor. With this layout a counterweight is impracticable, and the machine and motor, therefore, have to be large enough to raise not only the load placed upon the platform but also the weight of the platform itself, and this arrangement is therefore known as an unbalanced lift.

**Reduction of Noise.**

As the number of steel-framed buildings increases so does the problem of acoustics grow greater, and to

make matters worse there is a growing demand for quietness. To meet these conditions the lift engineer is faced with the problem of eliminating any vibration that is transmitted from the lift through the building steelwork and to reduce air-borne noises to a minimum. As each building has its own peculiar acoustic properties no hard-and-fast rules can be laid down, but, in general, alternating-current equipment, by virtue of the pulsating current, is more troublesome than direct-current equipment, and motor manufacturers have done much in recent years in producing quiet-running motors. Transmitter noise can be reduced to a minimum by insulating the machine from its supporting steelwork by using one of the many resilient materials now obtainable, and air-borne noise can be reduced by avoiding unnecessary openings in the machine-room and keeping the essential openings as small as practicable. Access doors should be made of hardwood of adequate thickness. Open lift wells should be avoided wherever possible. In some instances it is necessary to line the machine-room walls with sound-absorbing quilting.

**Service Lifts.**

Before leaving the subject of layout arrangements, mention should be made of service lifts. A service lift may be defined as a lift having a car of such a size that it is impossible for a person to ride in it; service lifts are therefore confined to the transport of parcels, food, letters, books, and the like. Whilst it is provided with a machine, controller, operating buttons, and guides of the same principle as for larger lifts, safeties are seldom fitted to the car, and the usual type of

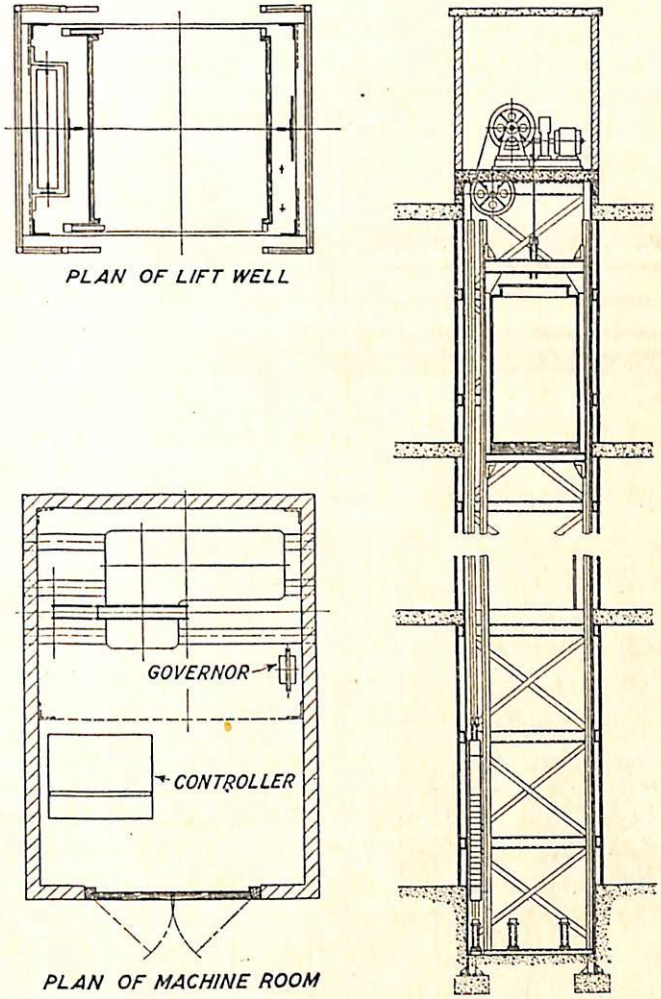



FIG. 13.—LIFT LAYOUT FOR CAR OPENING AT BACK AND FRONT. Note the diverting pulley in order that the ropes will lead plumb to their anchorages.

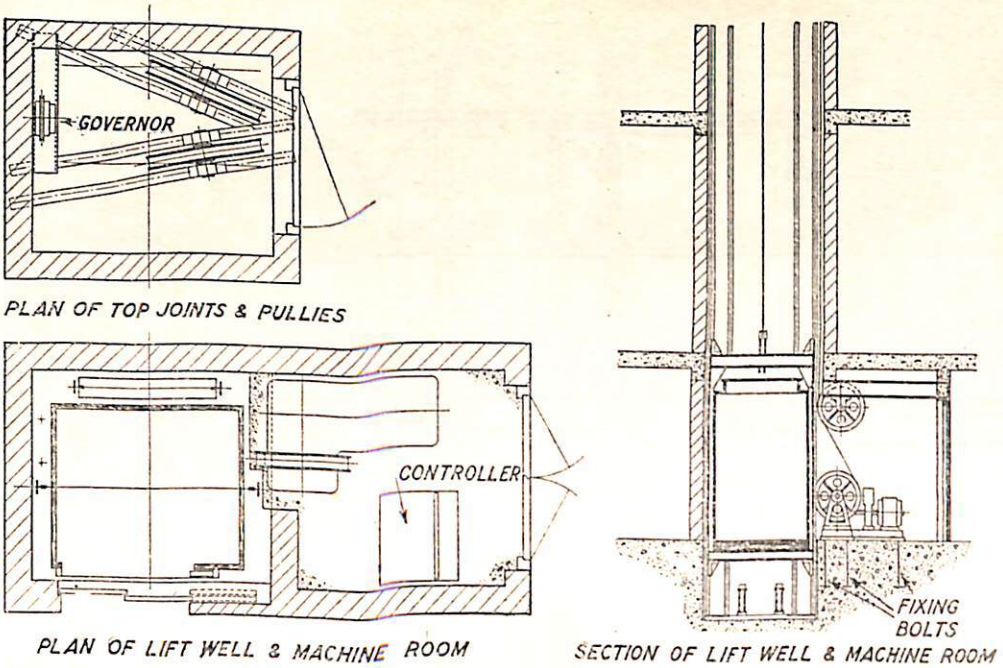

GOVERNOR
PLAN OF TOP JOINTS & PULLIES
CONTROLLER
PLAN OF LIFT WELL & MACHINE ROOM
FIXING BOLTS
SECTION OF LIFT WELL & MACHINE ROOM

FIG. 14.—LAYOUT WHERE MACHINE HAS TO BE INSTALLED AT BOTTOM AND ADJACENT TO LIFT WELL.

In the above arrangement it is assumed that site conditions preclude machine from being placed with its sheave in lift well, necessitating use of diverting pulley.

combined electro-mechanical locks is not necessary for locking the landing doors or shutters. Moreover, it is seldom necessary to make provision for a separate machine-room and pit, because these can be arranged in the enclosure which forms the lift well, as shown in Fig. 19. The control for a service lift may consist of a full set of buttons at each floor so that the car can be called to any floor from any other floor or dispatched to any floor from any other floor. Alternatively, a full set of buttons can be fitted in, say, the kitchen, and a call-push together with a dispatch-push at each of the other floors.

## DUTY AND CONTROL CONSIDERATIONS.

When deciding upon the duty, i.e. the load and speed, of a single lift, three factors have to be considered, namely, capital outlay, height of the building, and the load to be raised. For a goods lift, the load is easily determined by the maximum weight that is encountered in the normal process of the work carried out, and for buildings of, say, four floors, 100 ft. per min. would suffice for loads of up to about a ton; for more floors the speed should be increased, and the cost would increase for the higher speed as well as the higher rise. For heavier loads, the speeds should be decreased unless the saving in time warrants the additional expense.

The load for a single passenger lift is not so easily determined, because the load can consist of any number of persons, and the general size and nature of the building must be considered. An economical duty for a private residence is four persons or 600 lb.

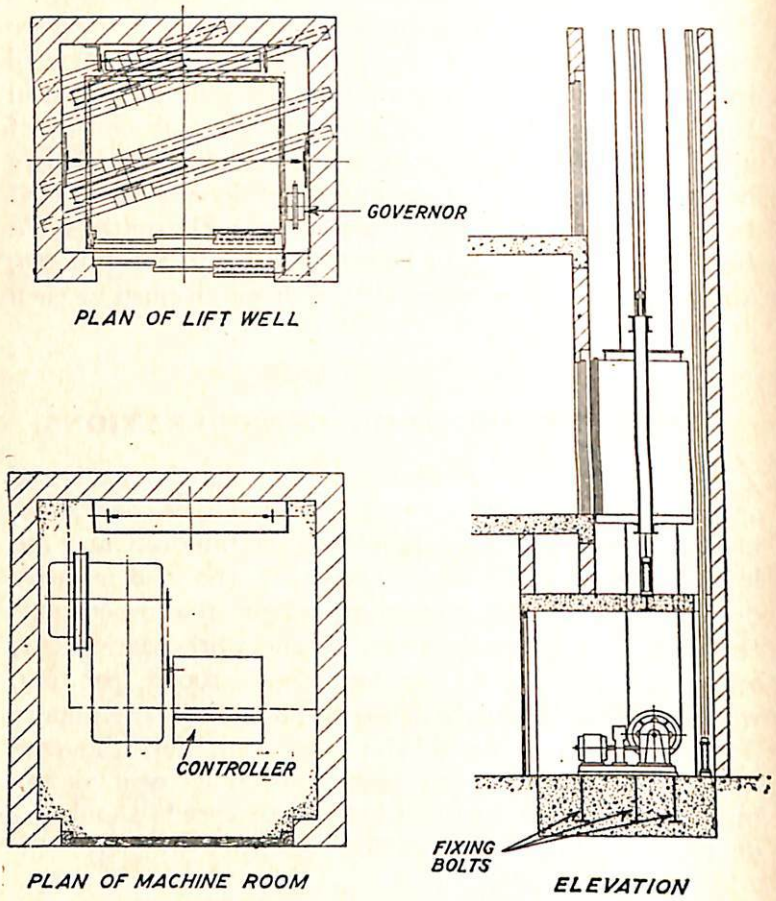



FIG. 15.—ARRANGEMENT WITH MACHINE BELOW, ITS SHEAVE BEING DIRECTLY UNDER LIFT WELL.

This layout is particularly useful when the lowest floor served is above the machine room.

at a speed of 100 ft. per min., and similarly for a small private hotel the duty should be increased to, say, eight persons at a speed of about 100 ft. per min.

In office buildings, where not more than one lift is warranted, and the rise is not more than five floors, a speed of not less than 150 ft. per min. and a load of 12 persons should be selected.

For higher rises the speed should be increased. The object in having a car capacity of not less than 12 persons is to meet the peak periods that occur with the morning incoming traffic and the outgoing traffic at night.

## INFLUENCE OF LIFT CONTROL ON SPEED OF LIFT SERVICE.

Before discussing the lift installation for a large building, it would be an advantage to show the different times taken to travel a given distance at a given car speed with the different rates of acceleration and retardation obtained with rheostatic and variable-voltage control. Referring to the typical time/distance curves shown in Fig. 20, it will be observed that with a car speed of 350 ft. per min. the time taken to travel from one floor to the next floor, a distance of 15 ft., is over 35 per cent. longer with rheostatic control than with variable-voltage control. It will now be realised that although gearless machines were intended for high car speeds and high rises, their higher rate of acceleration and retardation makes them eminently suitable for floor-to-floor service in busy office buildings and department-stores.

**Where Escalators are Preferable.**

Where floor-to-floor traffic is particularly heavy, such as in department-stores, one escalator will carry more passengers per hour than several lifts. The capacities of the usual store-type escalators are as follows:

2-ft.-wide escalator will carry 4,000 persons per hour.
3-ft.-wide escalator will carry 6,000 persons per hour.
4-ft.-wide escalator will carry 8,000 persons per hour.

## DECIDING ON ATTENDANT- OR AUTOMATICALLY-OPERATED LIFTS.

The first consideration to be given to a proposed installation of lifts is the method of operation. For an office building that is occupied by several companies it is advisable to have attendant-operated lifts, so that the many visitors to such buildings may receive the necessary attention and be taken to their destination; department-store lifts are invariably attendant-operated. With high-speed lifts of about 450 ft. per min. and over it is necessary to have high-speed, power-operated car and landing doors to take full advantage of the high car speed, and lift attendants are then required.

For buildings where the traffic is not intense attendants are not essential, and automatically operated lifts can be installed up to a speed of about 400 ft. per min. To meet the condition of the peak periods in the morning and evening it is possible to have the lifts arranged for attendant operation during these peak periods and for automatic operation at other times.

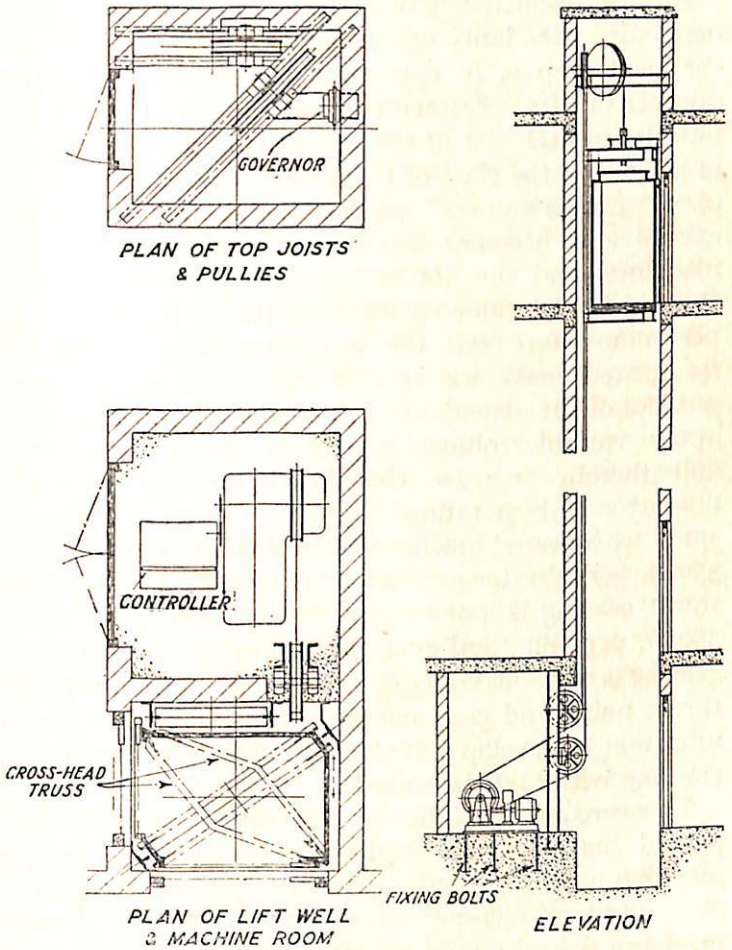



FIG. 16.—ANOTHER ARRANGEMENT FOR MACHINE AT BOTTOM OF LIFT WELL.

Note that in this case the car is opened on adjacent sides.

**Car Speeds with Geared Machines.**

Having decided whether the class of the building demands attendant- or automatically-operated lifts, the next step is to determine the load, speed, and number of lifts necessary to meet the expected traffic, but the capital cost of the installation must be borne in mind. If the class of building is such that the cost of a variable-voltage, gearless installation would be excessive it becomes necessary to substitute geared machines, and the highest car speed advisable with this type of machine with rheostatic control is 300 ft. per min. Moreover, the usual methods of control for geared machines at this car speed require the services of lift attendants. It is possible, however, to apply variable-voltage control to geared machines and thereby increase the speed for attendant or non-attendant operation to 350 ft. per min. The car speed with geared machines should be limited to about 350 ft. per min. for mechanical reasons, because whilst worm gearing is satisfactory for car speeds of up to 350 ft. per min., and even for higher speeds when the gearing is new, unavoidable wear occurs in the bearings, thrust units, and gear members, causing backlash and vibration to develop and result in noise and indifferent running with high car speeds.

To overcome the inherent difficulty associated with geared machines and high car speeds, the gearless machine was designed. The gearless machine is a slow-speed, direct-current motor with an electro-mechanical brake, and the shaft and bearings are of comparatively large dimensions to withstand the heavy loads imposed upon them. These two bearings are the only mechanical wearing parts of the machine,

and, owing to their large bearing surfaces, coupled with the slow speed at which the motor runs, the wear after many years' service is an infinitesimal amount.

**Car-speed Limitations due to Method of Control.**

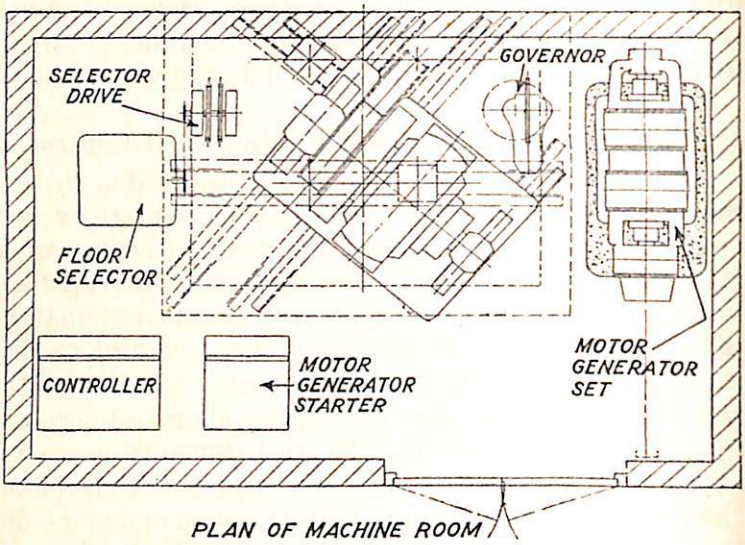
Apart from the limitation in car speed due to the mechanical reason just cited, further limitations are created by the method of control, operation, and type of geared machine. The application of variable-voltage control not only improves the rate and quality of acceleration but it enables a closer control of the motor to be maintained during retardation than with rheostatic control, thus permitting higher car speeds for automatic operation. No real difficulty exists in attaining a high speed with any type of lift machine: the difficulties are encountered in slowing and stopping the car at a predetermined landing with the floor of the car level with the landing and in keeping the distance travelled by the car during slowing within reasonable limits. These difficulties have been overcome by the use of gearless machines, variable-voltage control, multi-speed motors, and self-levelling machines.

**Car-speed Limitations Summarised.**

The limitations of car speeds with various types of machines and methods of operation will now be summarised in a general way.

The gearless machine with variable-voltage control is suitable for all car speeds of over 350 ft. per min.; speeds slower than 350 ft. per min. with gearless machines are not economical propositions.

For speeds of up to 450 ft. per min. non-attendant, i.e. automatic, operation can be employed, and for



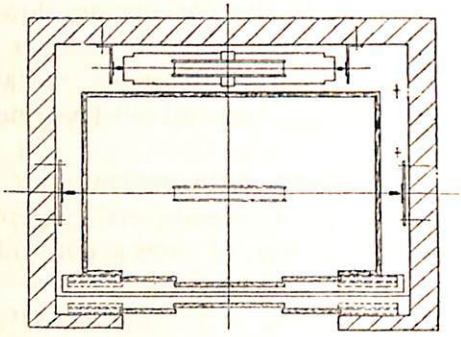



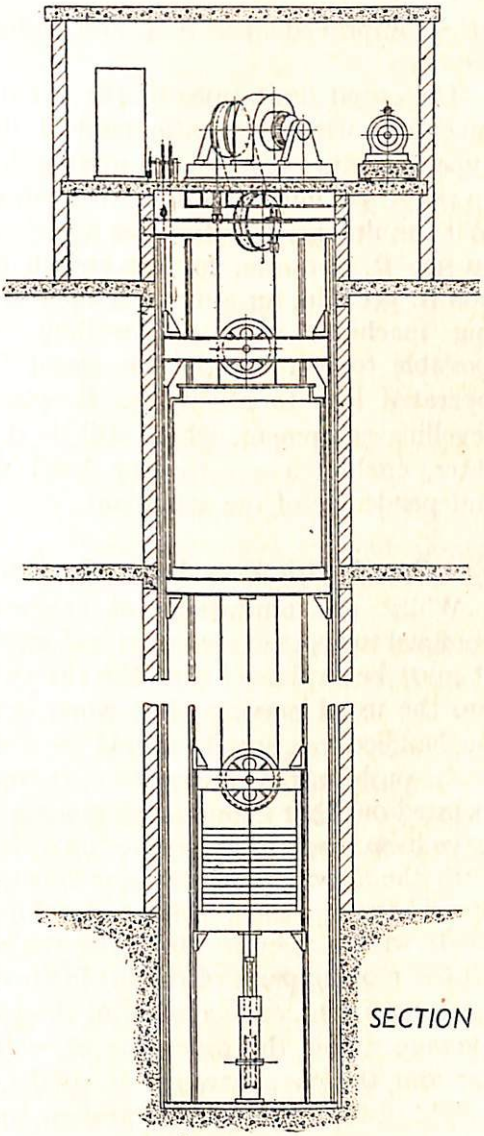

FIG. 17.—LAYOUT OF LIFT EMPLOYING GEARLESS MACHINE WITH VARIABLE-VOLTAGE CONTROL.

A sectional elevation is shown on opposite page.

higher speeds lift attendants are necessary. Many lifts operate at speeds of over 1,200 ft. per min. in New York.

**Speeds of Variable-voltage and Geared Machines.**

Variable-voltage machines are suitable for both attendant and automatic systems of operation with speeds of up to 350 ft. per min., and although this class of equipment is somewhat more expensive than the multi-speed, alternating current machine and its associated controller, it gives smoother acceleration and retard-



ation, improved operation, and reduced maintenance expense.

The speed limitations of the usual types of geared machines with rheostatic control depend upon the type of motor: single-speed motors limit the car speed to 150 ft. per min. for automatic push-button operation. With multi-speed motors car speeds can be increased to 300 ft. per min. for car switch operation and to 200 ft. per min. for automatic operation. By employing machines with self-levelling equipment it is possible to increase the car speed for automatically operated lifts to about 250 ft. per min. The self-levelling equipment, which will be described in detail later, enables a car to stop level with the landing independently of the attendant.

**Car Speed with Very Heavy Loads.**

Whilst the limitations of car speeds have been confined to types of machines and methods of operation it must be explained that the car speeds given above are the usual maxima, but when heavy loads are to be handled car speeds should be reduced, especially with push-button operation. It has already been pointed out that many developments in lift equipment have been made to overcome the difficulties associated with the slowing and stopping of medium- and high-speed lifts, and most of these developments have been made with a view to absorbing the kinetic energy of all the moving parts of the lift in the shortest space of time consistent with comfort of the passengers. With average duties the difference of weight between the car and the counterweight is small compared to the weight of the whole moving system, and, as the kinetic

energy is proportional to the square of the speed, it follows that the car speed is a more important factor than the load. When the load is unusually heavy, such as three tons, it becomes necessary to provide a machine with a multi-speed motor for a car speed of, say, 120 ft. per min., with car switch operation to assist in stopping a car level with the floor,. whereas for normal loads a single-speed motor would suffice for this class of operation at a speed of even 150 ft. per min.

**Use of Two-speed Control.**

Owing to the inherent flexibility of speed control with direct-current motors by means of shunt-field regulation it is possible to take advantage of two-speed control for medium duties on direct-current power supplies at comparatively small additional cost. With a load of 1,500 lb. at a speed of 150 ft. per min. on an alternating-current power supply it would be usual to furnish a single-speed motor for car switch operation because two-speed, alternating-current motors and the necessary additional contactors increase the cost by a considerable amount, but with direct-current motors the additional cost of the two-speed motor and controller is comparatively small and is justified by the advantages over single-speed control.

## TRAFFIC ANALYSIS.

Before determining a lift installation that will, all things considered, be most satisfactory for a given building, it is necessary to form as definite an idea as possible of the quantity and quality of the lift service

required. Exact determination of lift requirements is extremely difficult, because so many variables have to be taken into account and it is almost impossible to estimate what conditions may be encountered in the future. It will be realised, however, that although these difficulties exist the determination of an adequate and economical lift installation is very important and that the majority of developments have been made with a view to increasing the capacity of a lift installation of a given number of lifts per unit time.

The density of the population of a building ranges from about one person per 40 sq. ft. of net working floor area to one person per 150 sq. ft., the higher density being for department-stores and the lower ratio for office buildings occupied by one concern. During sales, a density of more than one person per 30 sq. ft. of sales area has been observed.

**Suitable Time-interval between Car Arrivals.**

No definite rules can be given for what is considered a satisfactory time-interval between the arrival of cars at a floor, for whilst a very short interval may be considered necessary in some buildings it is neither essential nor economical in others. An interval of 20 seconds is considered good service. Thirty seconds is an interval that may be too long for some buildings but satisfactory for others, and is necessary for economy. Intervals of 40 seconds or more are considered poor, although many buildings have intervals as high as 60 seconds without very serious objection on the part of the occupants. Naturally, however, for a building to have a good lift service it is necessary to have short intervals.

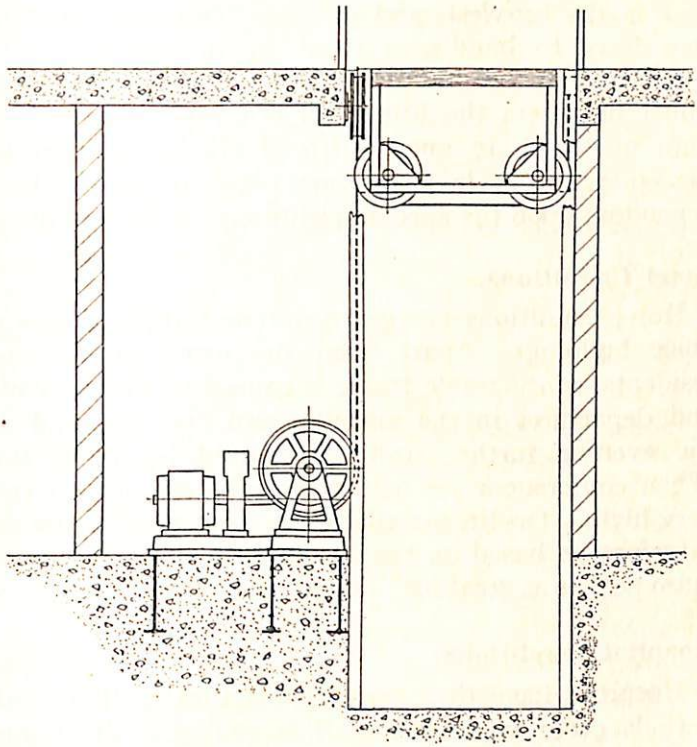


FIG. 18.—USE OF DRUM-TYPE MACHINE.
This shows a case where it is necessary to raise a platform to a level such as a loading bank, street level, or, say, the floor in a main banking hall, where any form of overhead support is impracticable. Advantage is taken of a drum-type machine.

**Traffic Conditions in Office Buildings.**

In office buildings the peak traffic occurs in the morning, at lunch time, and in the evening, and the heaviest peak will depend upon the class of business, luncheon facilities, discipline, and similar factors, which vary with each building. Generally the morning

peak is the heaviest, and in some buildings the lifts may have to handle as much as one-third of the population in five minutes when filling the building, whilst in others the lifts need not carry more than from one-tenth to one-twelfth of the population in the same time. The peaks vary between these values, depending upon the specific conditions of the building.

**Hotel Conditions.**

Hotel conditions are quite different from those in office buildings. Apart from the usual number of residents, considerable traffic is caused by the arrivals and departures in the morning and evening, and in the evening further traffic is caused by banquets. When conferences are held the peaks are apt to run very high. The lift installation in a busy hotel should therefore be based on the assumption that the maximum peak is as great for "down" as for "up" journeys.

**Hospital Conditions.**

Hospitals have their own peculiarities in that peak periods occur when the staff is changing duty and during visiting hours. Whilst large cars are desirable for the handling of patients care should be taken that the cars are no larger than necessary, because the carrying capacity of the lift should be based on the car area for passenger service, and unnecessarily large cars, therefore, make the lifts expensive. Wherever possible lifts for handling patients should be separate from those used for visitors and the staff. It is an advantage to install service lifts with stainless-steel cars having coved corners for the transport of dressings, specimens, and the like.

**Determining the Most Satisfactory Car Size.**

Having ascertained the likely traffic in a building the next step is to determine the most satisfactory car size. To facilitate the transfer of passengers cars should be made wider than their depth: a car 6 ft. wide and 5 ft. deep can accommodate, with normal loading, fifteen passengers, which is equivalent to a loading of 2,250 lb. Similarly, a car 6 ft. 6 in. wide by 5 ft. 6 in. deep can accommodate eighteen passengers, which corresponds to a load of 2,700 lb. If, however, such size cars were for service in a department-store the carrying capacity would have to be increased to 3,000 lb. and 3,600 lb. respectively to meet the tendency to overcrowding, especially during sale times.

**Methods of Operation for Car and Landing Doors.**

When heavy traffic is encountered it is essential to have power-operated car and landing doors. For many installations collapsible car gates with manually opened and automatically closing doors will suffice, but, apart from the fact that such gates and doors take longer to operate than power-operated doors, the work becomes strenuous on a busy lift. When doors and gates are manually operated no definite time can be given for either opening or closing, but in order to arrive at some figure at least one second should be added to the times for power-operated doors. With two-speed, power-operated doors the time to open and close the doors for a 4-ft. lift entrance and start the lift may be taken as 4 seconds, and for two-speed, centre-opening doors for similar-width entrance the time is reduced to approximately 3 seconds. With department-stores, where passengers

move more leisurely than in office buildings, these times should be increased by 10 per cent.

**Probable Stops.**

In order to arrive at the round-trip time, that is, the time taken for a car to load and leave the ground floor, stop at the various floors for discharging passengers on its "up" journey to fill the building, and return to the ground floor, it is necessary to determine the number of stops the car will make in a round trip. To take into account the distribution of passengers, the number of persons available at the ground floor when a car arrives for loading, and the possible inter-floor traffic, would require very complicated formulæ, and for purposes of comparison of different types of lifts is unnecessary.

When a lift serves two floors above the ground floor the car will not stop at both floors in every trip but will do so for almost every trip, and the average number of stops per trip will be slightly less than two. With many floors served the average number of stops will be some percentage of the total number of floors.

**Calculating the Average Number of Stops.**

By resorting to the "mathematics of probability" a formula can be evolved to determine the average number of stops that will be made to discharge passengers in the peak period of filling the building.

Let $n$ = total number of persons going into the building.

$a$ = number of persons on one floor.

$b$ = number of persons on another floor.

$c$ = number of persons on another floor, etc.

Then $n = a + b + c + d \ldots$ etc.

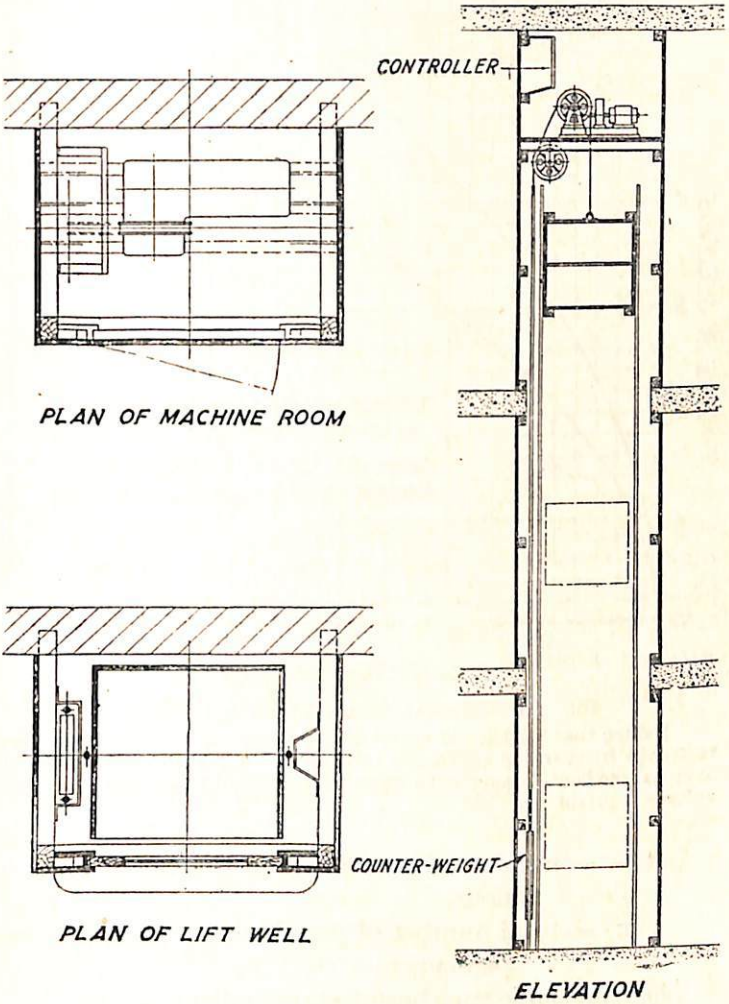



FIG. 19.—SERVICE LIFT.

The machine can be arranged in the enclosure which forms the lift well.

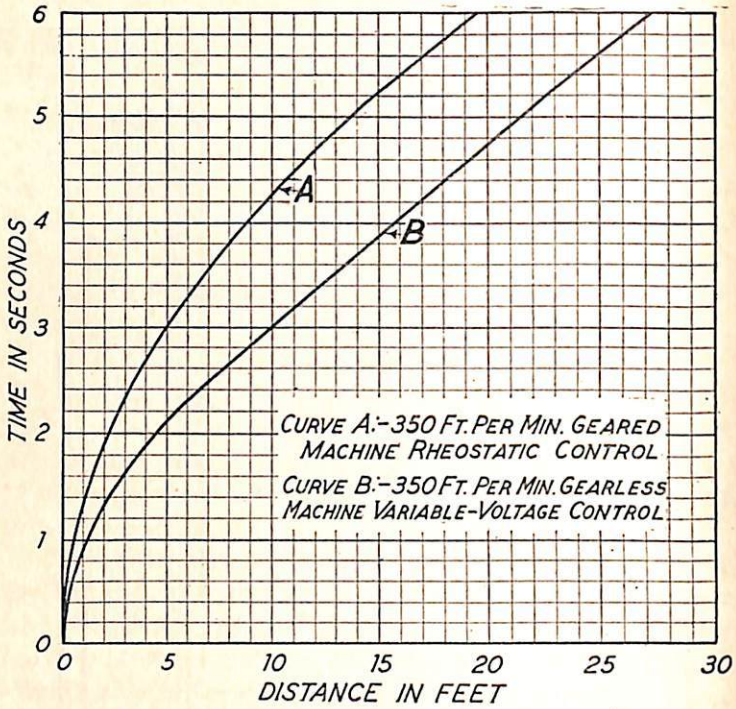



FIG. 20.—TYPICAL TIME-DISTANCE CURVES.

Notice that with a car speed of 350 ft. per min., the time taken to travel from one floor to the next floor—a distance of 15 ft.—is over 35 per cent. longer with rheostatic control than with variable-voltage control.

Let $p$ = number of passengers in the car at loading floor.

$s$ = total number of possible stops to discharge passengers.

Then probable number of stops will be—

$$s - \left(\frac{n-a}{n}\right)^p - \left(\frac{n-b}{n}\right)^p - \left(\frac{n-c}{n}\right)^p \ldots \text{etc.}$$

the total number of minus terms being equal to $s$.

If one of the stops is a terminal stop that is made every trip the corresponding term is omitted.

When the number of persons on each floor is the same—$a = b = c = d \ldots$ etc.

Then $sa = n$, and the formula for probable stops is reduced to—

$$s - s\left(\frac{s-1}{s}\right)^p$$

When one of these stops is a fixed stop, then the formula for the probable stops per trip becomes—

$$s - (s - )\left(\frac{s-1}{s}\right)^p$$

The curves shown in Fig. 21 are plotted from this formula and are suitable for readily determining the number of probable stops in the peak period of filling a building, assuming that the same number of persons is on each floor served by the lift. The results from the above formula compare favourably with those found in actual practice, and the formula has the advantage of giving a definite basis for comparison of different types of lifts.

**Time-allowance for Attendants' Faults.**

It will be appreciated that with car switch operation where more than one speed is available it is possible for the lift attendant to run the lift at slow speed for an unnecessarily long period, and so lose time; moreover, unless the lift is provided with some form of floor-levelling device, time may be lost in inching the car level with the floor. At car speeds of about 500 ft. per min. much concentration, skill, and practice are

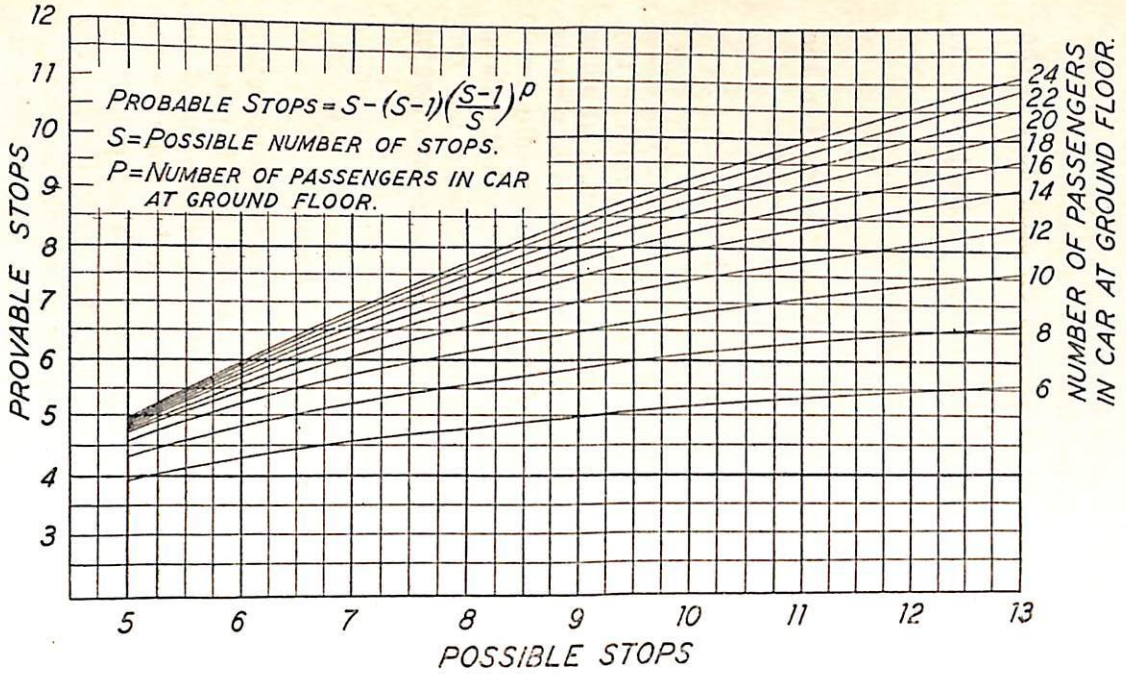



FIG. 21.—CURVES FOR READILY DETERMINING THE NUMBER OF PROBABLE STOPS IN THE PEAK PERIOD OF FILLING A BUILDING.

This assumes that the same number of persons is housed on each floor served by the lift.

necessary for attendants to make accurate floor stops without loss of time, and the work soon becomes strenuous on busy lifts. These disabilities, however, have been overcome with automatic operation, which will be described later, and all operations, with the exception of the time taken by the transfer of passengers, are timed and automatically carried out. In order, therefore, to make allowance for the difference in time taken for slowing at the terminal floors with different types of control, it is usual to allow three seconds at each terminal landing for rheostatic control and one second for variable-voltage control. When no automatic floor-levelling device is fitted an additional time of two seconds per stop for 50 per cent. of the probable stops should be allowed for inching.

**Time required for Passengers to move in and out of Car.**

The most difficult and indefinite time to determine is the time required for passengers to move into and out of a car. This time depends upon the dimensions of the car, the width of door opening, the class of building, the intensity of the traffic, and the number of passengers already in the car. With average service conditions and a car suitable for about fifteen persons the average time taken for one person to enter an almost loaded car is 3.5 seconds, and to enter an almost empty car is 0.75 second. This difference in time is due to the person entering the car being compelled to wait for those already in it to make room. The time taken for, say, seven persons to enter the car when eight passengers are already in it is about 10.5 seconds, or 1.5 seconds per person. For passengers

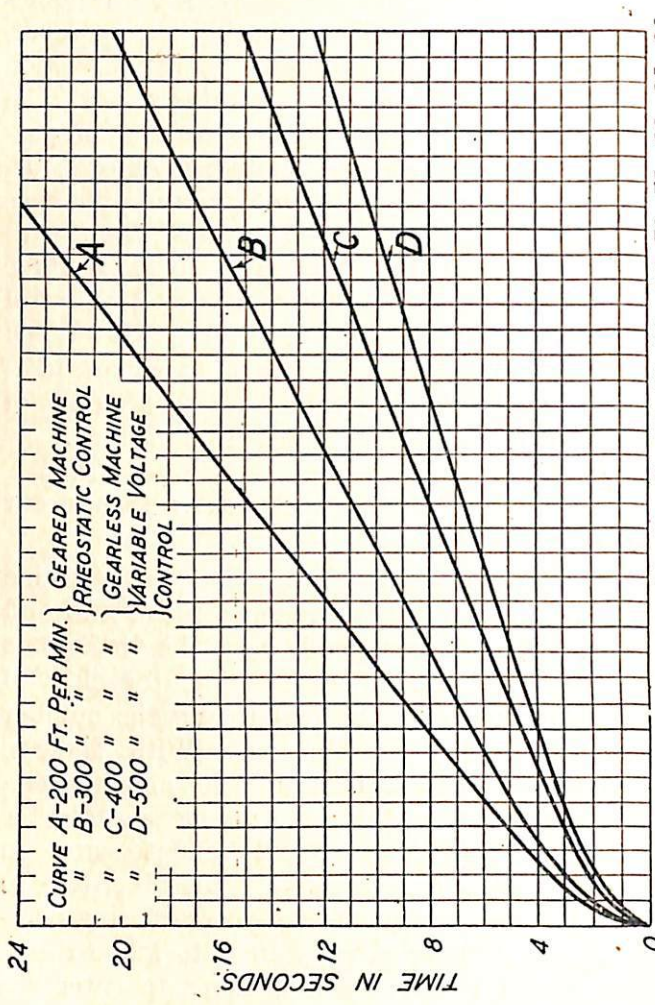



FIG. 22.—AVERAGE TIMES FOR TRAVELLING VARIOUS DISTANCES AT DIFFERENT CAR SPEEDS.

to leave a car more time per person must be allowed, because those at the front of the car often have to make way for those at the back to leave. With a full car 4 seconds should be allowed for one person to leave, but for one person to leave when up to five passengers are in the car this time can be reduced to 1.5 seconds. For a full car to empty, about 12 seconds, or 0.8 second per person, should be allowed. The above-mentioned times include the time taken in preparing to close the gates or doors.

**Selecting the Car Speed.**

The selection of car speed is primarily dependent upon the travel of the lift and then upon the capital cost. For busy buildings having a height of about 100 ft. the speed should be from 400 to 500 ft. per min., and for lower buildings with intermittent service the speed can be reduced. The limitations of speed with different classes of equipment have already been discussed, and the average times for travelling various distances at different car speeds can be taken from the distance/time curve in Fig. 22.

**Calculating the Size and Number of Lifts Necessary.**

The round-trip time is obtained by adding together the detailed times as selected from those given in the foregoing for the particular type of lift under consideration. A certain amount of time, due to the human element, escapes calculation, and it is therefore advisable to increase the calculated round-trip time by, say, 10 per cent.

Having obtained the round-trip time, the time-interval for a battery of lifts is equal to the round-trip

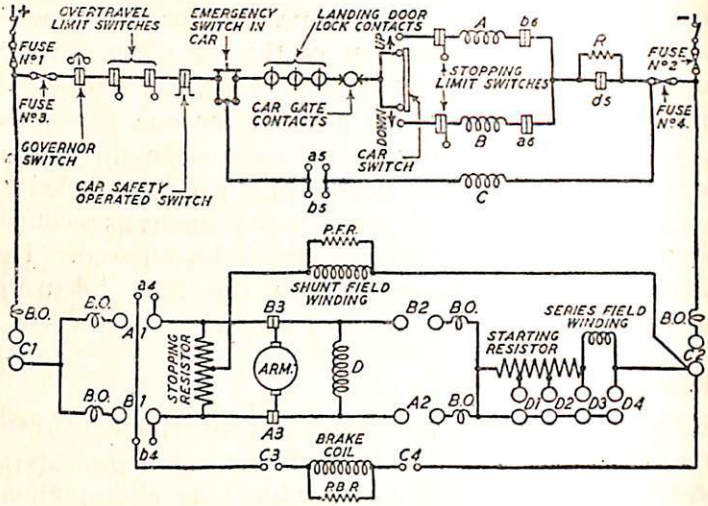



FIG. 23.—*A*—"UP" REVERSING CONTACTOR. *B*—"DOWN" REVERSING CONTACTOR. *C*—MAIN CONTACTOR. *D*—ACCELERATING SWITCH. *B.O.*—BLOW-OUT COILS.

time divided by the number of lifts in the battery. The capacity of one lift in five minutes is determined by dividing 300 seconds by the round-trip time in seconds and multiplying the result by the number of passengers carried per round trip. The number of lifts necessary to give the required service is obtained by dividing the required five-minute capacity by the calculated five-minute capacity of one lift.

We give below details of circuit arrangements for three popular types of electric lifts.

## SINGLE-SPEED CAR-SWITCH-OPERATED D.C. LIFT.

**Explanation of Wiring Diagram.** (Fig. 23.)

The typical wiring diagram is shown with controller

contactors in "off" position with lift at rest and all landing doors and car gate closed.

STARTING.

Commencing at main "+" switch, current flows from fuses Nos. 1 and 3 through the various switches to common contacts in car-switch.

By moving car-switch handle to "up" position, circuit is completed through "up" car-switch contacts, coil (*A*) of "up" reversing contactor, interlock contacts (*b*6), auxiliary contacts (*d*5) of accelerating switch to "—" main, and thus the "up" reversing contactor is energised.

Main making contacts (*A*1) and (*A*2) then close and main breaking contacts (*A*3) open; similarly, all auxiliary making contacts marked (*a*) close and all auxiliary breaking contacts marked (*a*) open.

Closing of contacts (*a*5) causes main contactor (*C*) to be energised, and closing of its contacts (*C*1) and (*C*2) completes circuit from "+" main through contacts (*A*1), (*B*3), armature, contacts (*A*2), starting resistor, and series field winding to "—" main.

Shunt field winding circuit is completed by closing of the contacts (*C*1), (*A*1), and (*C*2), Brake coil is energised when the contacts (*C*1), (*A*1), (*a*4), (*c*3), (*c*4), and (*C*2) close.

As the motor armature accelerates, voltage across coil (*D*) of accelerating switch increases and accelerating switch contacts (*D*1), (*D*2), (*D*3), and (*D*4) close in numerical order to short-circuit starting resistor and finally series field winding.

Opening of contacts (*d*5) inserts resistance (*R*) in reversing contactor-coil circuit to prevent sudden

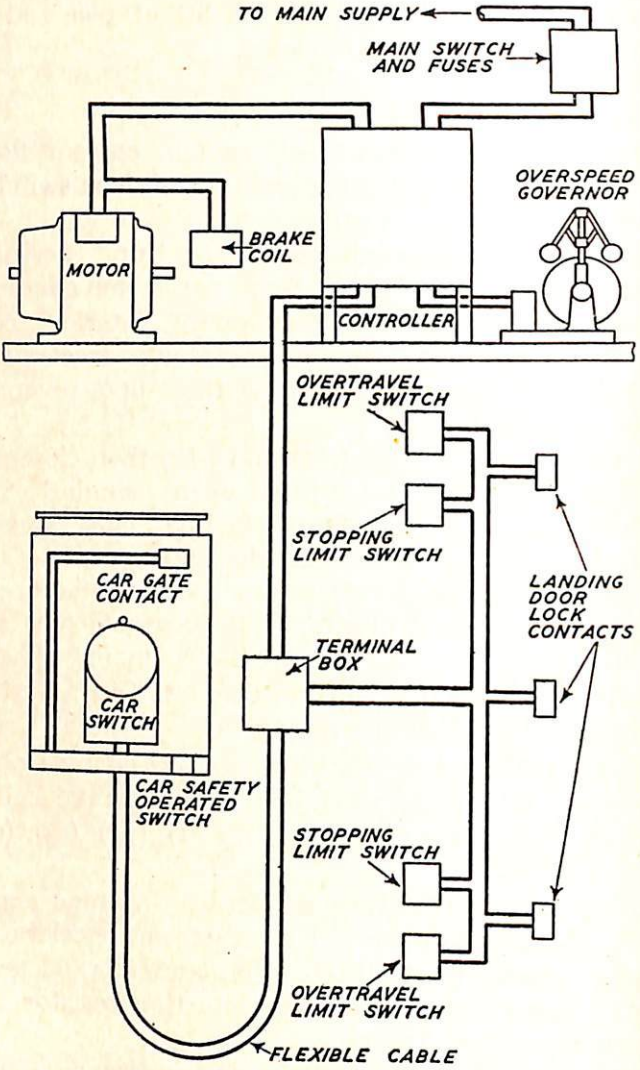



FIG. 24.—MAIN ELECTRICAL COMPONENTS FOR SINGLE-SPEED CAR-SWITCH-OPERATED D.C. LIFT.

reversal of motor and to ensure that starting resistor is in circuit before starting motor.

By moving car-switch handle to "down" position a similar sequence of operation is produced, excepting that "down" reversing contactor (*B*) closes, and closing of contacts (*B*1) and (*B*2) and opening of contacts (*B*3) cause current in motor armature to flow in reverse direction to that when car is ascending.

STOPPING.

The lift is stopped normally by centring of car-switch handle, or by opening of stopping limit switch at a terminal landing. An emergency stop is made by opening of emergency switch in car, operation of governor switch, an overtravel limit switch, or car safety operated switch. Opening of a reversing contactor (*A*) or (*B*) and main contactor (*C*) interrupts power supply to motor and brake, thereby causing lift to stop. Mechanical braking is assisted by dynamic braking; the dynamic braking circuit is through stopping resistor and is completed by closing of contacts (*A*3) and (*B*3).

**Main Electrical Components and their Functions.**

MOTOR.

Fitted to lift machine. Provides necessary motive power for raising and lowering car.

CONTROLLER.

Governs starting, stopping, and direction of rotation of lift motor in response to operation of car switch, limit switches, and protective devices.

ELECTRO-MECHANICAL BRAKE.

Fitted to lift machine. When applied, it holds the car stationary. While motor is under power, brake is released.

CAR SWITCH.

Movement of car-switch handle causes car-switch contacts to close and so actuate controller contactors.

CAR-GATE CONTACT.

Ensures that car gate is closed while lift is being operated.

LANDING-DOOR LOCKS.

Ensure that a landing door cannot be opened unless car is opposite to that door and that lift cannot be operated unless all doors are closed.

STOPPING LIMIT SWITCHES.

When operated, these stop car at terminal landings independently of car switch.

OVERTRAVEL LIMIT SWITCHES.

These stop car when it passes normal limits of travel, independently of car switch or stopping limit switches.

CAR SAFETY OPERATED SWITCH.

Interrupts operating circuit and so stops lift machine in event of car safety mechanism being applied.

OVERSPEED GOVERNOR.

Causes car safety mechanism to be applied in event of descending car speed exceeding a predetermined

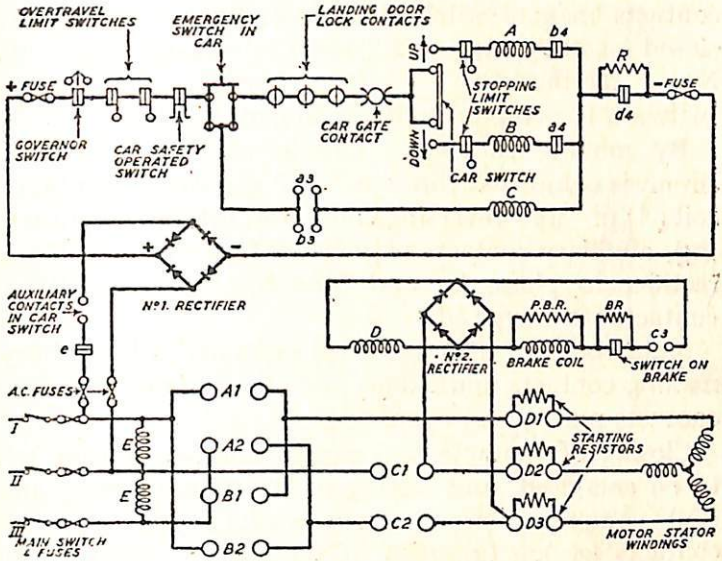



FIG. 25.—*A*, "UP" REVERSING CONTACTOR. *B*, "DOWN" REVERSING CONTACTOR. *C*, MAIN CONTACTOR. *D*, ACCELERATING CONTACTOR. *E*, PHASE-FAILURE RELAY.

value. Governor switch opens operating circuit in event of excessive car speed and so stops lift.

## SINGLE-SPEED CAR-SWITCH-OPERATED A.C.-D.C. LIFT.

**Explanation of Wiring Diagram.** (Fig. 25.)

The typical wiring diagram is shown with controller contactors in "off" position with lift at rest and all landing doors and car gate closed.

STARTING.

Commencing at main switch, phase I, current flows from A.C. fuse, through contacts (*e*), auxiliary

contacts in car switch (these auxiliary contacts are closed for both "up" and "down" directions), through No. 1 rectifier to "+" fuse, through the various switches, to common contacts in car switch.

By moving car-switch handle to "up" position, circuit is completed through "up" car-switch contacts, coil (*A*) of "up" reversing contactor, interlock contacts (*b*4), auxiliary contacts (*d*4), "—" fuse, through No. 1 rectifier to phase II, and thus the "up" reversing contactor is energised.

Main contacts (*A*1) and (*A*2) close and all auxiliary making contacts marked (*a*) and all auxiliary breaking contacts marked (*a*) open.

Closing of contacts (*a*3) causes main contactor (*C*) to be energised, and closing of its contacts (*C*1) and (*C*2) completes circuit from main switch through contacts (*A*1), (*A*2), (*C*1), (*C*2), starting resistors, to motor stator windings.

Coil (*D*) of accelerating contactor is energised by closing of contacts (C1) and (*C*2), through No. 2 rectifier. Brake-coil circuit is completed from the same rectifier by the closing of contacts (*C*3).

Starting resistors are short-circuited by closing of main contacts (*D*1), (*D*2), and (*D*3). While motor is running, switch on brake is opened and economy resistance (*BR*) is inserted in brake-coil circuit. Similarly, economy resistance (*R*) is inserted in reversing and main contactor circuit by the opening of auxiliary contacts (*d*4).

By moving car-switch handle to "down" position a similar sequence of operation is produced excepting that "down" reversing contactor (*B*) closes, and closing of contacts of (*B*1) and (*B*2) interchanges the

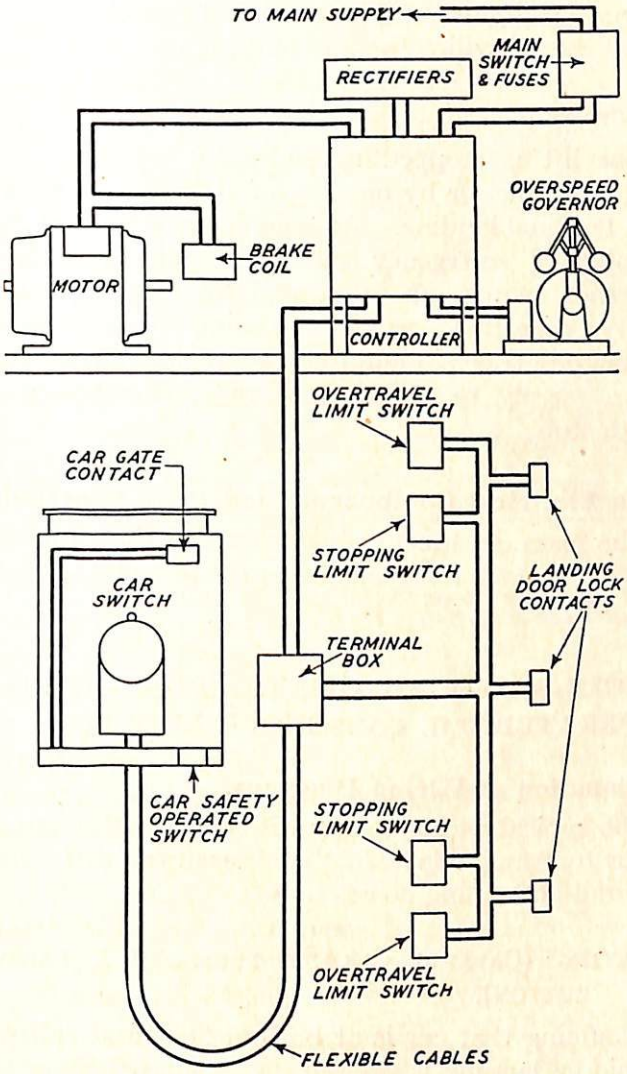



FIG. 26.—MAIN ELECTRICAL COMPONENTS FOR SINGLE-SPEED CAR-SWITCH-OPERATED A.C./D.C. LIFT.

connections between the motor and power supply and so reverses the direction of rotation.

STOPPING.

The lift is stopped normally by centring of car-switch handle, or by opening of stopping limit switch at a terminal landing. An emergency stop is made by opening of emergency switch in car, operation of governor switch, an overtravel limit switch, or car safety operation switch. Opening of a reversing contactor (*A*) or (*B*) and main contactor (*C*) interrupts power supply to motor and brake, thereby causing lift to stop.

**Main Electrical Components and their Functions.**

The main electrical components and their functions are the same as for a single-speed car-switch-operated D.C. lift.

## SINGLE-SPEED AUTOMATIC PUSH-BUTTON-OPERATED D.C. PASSENGER LIFT. (Fig. 27.)

**Explanation of Wiring Diagram.**

The typical wiring diagram is shown with controller contactors and relays in "off" position with lift at rest and all landing doors closed.

STARTING (CALLING CAR BY PRESSING A LANDING BUTTON).

Assuming that car is at bottom floor and call push at middle landing is pressed. Current will flow from fuses Nos. 1 and 3 through the various contacts shown

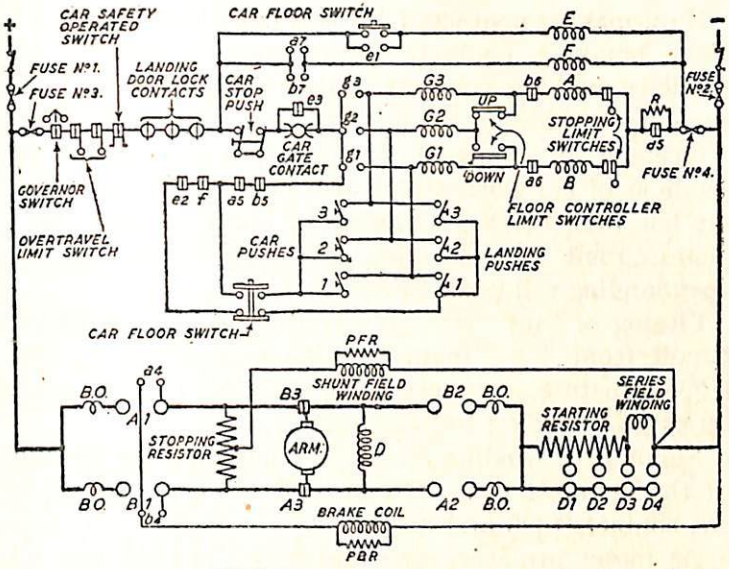



FIG. 27.—*A*, "UP" REVERSING CONTACTOR. *B*, "DOWN" REVERSING CONTACTOR. *D*, ACCELERATING SWITCH. *E*, CAR-HOLDING RELAY. *F*, TIME RELAY. *G*, FLOOR RELAYS.

to and through stop push in car, contacts (*e*3), contacts (*b*5), and (*a*5), (*f*), (*e*2), car-floor switch to common of landing pushes.

Pressing No. 2 landing push completes circuit through coil of floor relay (*G*2), "up" limit switch of floor controller, interlock contacts (*b*6), coil (*A*) of "up" reversing contactor, "up" stopping limit switch, contacts (*d*5), operating fuse No. 4, to "—" main. Thus "up" reversing contactor and floor relay (*G*2) are energised. Energising of floor relay (*G*2) causes its contacts (*g*2) to close, and floor relay (*G*2) and "up" reversing contactor (*A*) are thus held closed until car arrives at middle floor.

Main making contacts ($A1$) and ($A2$) then close and main breaking contacts ($A3$) open; similarly, all auxiliary making contacts marked ($a$) close and all auxiliary breaking contacts marked ($a$) open.

Opening of contacts ($a5$) interrupts circuit to common of car pushes and also landing pushes after car has been started. Closing of contacts ($a7$) completes circuit for time relay ($F$) and its contacts ($f$) open landing call push circuit.

Closing of "up" reversing contactor ($A$) completes circuit from "+" main through contacts ($A1$) and ($B3$), armature, contacts ($A2$), starting resistor, and series field winding to "—" main.

Shunt field winding circuit is completed by closing of the contacts ($A1$). Brake coil is energised when the contacts ($A1$) and ($a4$) close.

As motor armature accelerates, voltage across coil ($D$) of accelerating switch increases and accelerating switch contacts ($D1$), ($D2$), ($D3$), and ($D4$) close in numerical order to short-circuit starting resistor and finally series field winding.

**Main Electrical Components and their Functions.**

*Main Controller.*—Governs starting, stopping, and direction of rotation of lift motor in response to pressing of car and landing push buttons, limit switches, and protective devices.

*Floor Controller.*—Enables car to be called or dispatched to any particular floor, where it automatically stops.

*Car Push Box.*—This houses pushes by which car is dispatched to required floor and stopped in emergency.

*Landing Call Pushes.* Pressing of landing call push

causes car to start and proceed to floor at which button was pressed.

*Car-floor Switch.*—This is actuated by movable car floor when car is occupied and, in conjunction with a relay, renders landing call pushes inoperative, prevents operation of lift unless car gate is closed, and completes circuit for car pushes.

*Other Components.*—The other items of equipment shown in the diagram function in the same manner as described for a car-switch-operated D.C. lift.

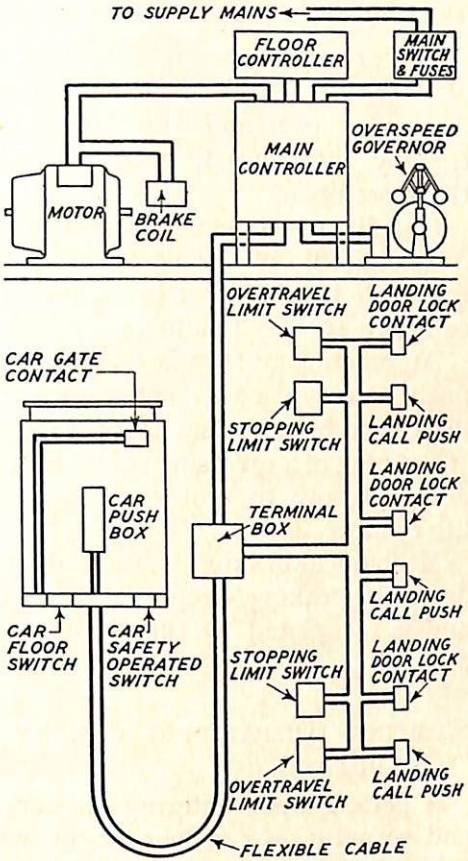



FIG. 28.—MAIN ELECTRICAL COMPONENTS FOR SINGLE-SPEED AUTOMATIC PUSH-BUTTON-OPERATED D.C. PASSENGER LIFT.

Opening of contacts ($d5$) inserts resistance ($R$) in reversing contactor-coil circuit to prevent sudden reversal of motor and to ensure that starting resistor is in circuit before starting motor.

STOPPING.

As car approaches middle floor, "up" limit switch of floor of controller is opened and holding circuit of floor relay (*G*2) and "up" reversing contactor (*A*) is thereby interrupted, and this relay and contactor therefore open.

Opening of contacts (*a*7) causes time relay (*F*) to be de-energised, but closing of its contacts (*f*) is delayed to enable landing door to be opened before car can be called to another landing.

An emergency stop is made by pressing of car stop push or operation of governor switch, an overtravel limit switch, or car safety operated switch.

Opening of a reversing contactor (*A*) or (*B*) interrupts power supply to motor and brake, thereby causing lift to stop.

Mechanical braking is assisted by dynamic braking: dynamic braking circuit is through stopping resistor and is completed by the closing of the contacts (*A*3) and (*B*3).

STARTING (DISPATCHING CAR BY PRESSING A CAR BUTTON).

A person, upon entering the car, depresses car floor and so actuates car-floor switch which opens landing push circuit, closes car push circuit, and, as soon as landing door is closed, completes circuit from "+" main through fuses Nos. 1 and 3, through governor switch, overtravel limit switches, car safety operated switch, landing-door lock contacts, car-floor switch coil of car-holding relay (*E*), fuse No. 4, to "—" main. Energising of relay (*E*) causes its contacts (*e*1) to short-circuit appropriate contacts of car-floor switch and

thus provide a holding circuit for car-holding relay (*E*) until a landing door is opened.

Pressing of a car button causes current to flow from "+" main through fuses Nos. 1 and 3, protective devices, landing-door lock contacts, car stop push, car-gate contact, contacts (*b*5) and (*a*5), car-floor switch, to common of car pushes.

Assuming that car is at bottom floor and car push for the middle floor is pressed, current will flow from this push through coil (*G*2) of floor relay and coil (*A*) of "up" reversing contactor, and thus floor relay and reversing contactor are energised and held closed in the same manner to that as explained above when calling car to a landing.

If car had been standing at top floor and middle-floor push had been pressed, flow of current from the coil of relay (*G*2) would have been through "down" limit switch of floor controller to "down" reversing contactor (*B*). Operation would then be similar to that for "up" direction, excepting that closing of contacts (*B*1) and (*B*2) and opening of contacts (*B*3) would cause current in armature to flow in reverse direction to that when the car is ascending.

## CHAPTER II

# LIFT MACHINES

### Geared Machines.

A GEARED machine is now invariably assembled as a self-contained unit, comprising an electric motor, electro-mechanical brake, worm reduction gear, and winding drum or traction sheave, all mounted on a continuous bedplate. The worm reduction gear is suitably housed for the purposes of lubrication, and in conjunction with an outer bearing for supporting the mainshaft which carries the winding drum or traction sheave. By arranging the brake drum between the gearbox and motor it serves as a coupling to connect the worm shaft to the motor shaft. The bedplate may be made of cast iron or, alternatively, fabricated from rolled-steel sections welded together, but whichever form is employed it is essential that the bedplate is rigid when in service.

As some of the electrical equipment employed for a drum machine varies considerably from that for a traction sheave, the differences in these two machines will be described at some length and the details of the electrical components associated with these two types of machines will be explained later.

### Geared Drum Machines.

As previously mentioned, drum machines are now used only when site conditions are such that counterweights cannot be employed, and the application of

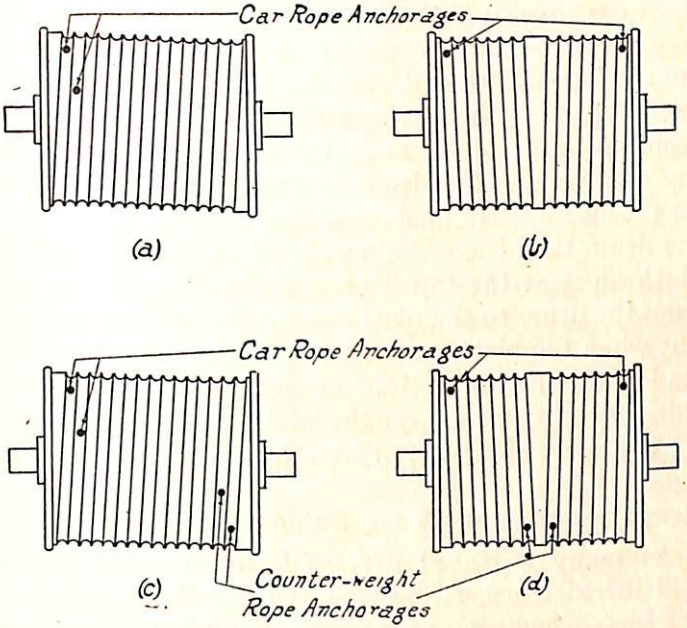



FIG. 29.—WINDING-DRUM ARRANGEMENTS FOR GEARED-DRUM MACHINES.

this type of machine is therefore now very limited. When the machine is installed at the lowest floor, as shown in Fig. 18, the winding drum is provided with two adjacent helical grooves extending the length of the drum, and both ropes are anchored to the drum at one end, as indicated in Fig. 29 (*a*).

When the machine is installed above the lift well, one half of the drum is provided with a single left-hand groove and the other half of the drum has a single right-hand groove, as shown in Fig. 29 (*b*). These different arrangements of grooving are necessary, because when a machine is installed "below," the

ropes pass over a pulley at the top of the lift well and they therefore have a plumb lead to the pulleys on the carriage of the platform, but when the machine is fixed "above," the angle of the ropes varies with the position of the platform in the lift well owing to the ropes traversing the drum as they are wound on and off the drum. By anchoring the ropes at the ends of the drum they leave the middle of the drum when the platform is at the top floor and the lead of the ropes from the drum to the platform is substantially vertical, but when the platform is at the bottom floor the ropes lead down the lift well at an angle, and the resulting side pull of one rope on the platform is compensated by the side pull of the other rope.

**Drum Arrangements for Balanced Lifts.**

As many balanced lifts with drum machines are still in existence, it may be of interest, especially to the service engineer, to mention that when the machine is fitted "below," the drum is grooved the same hand for its entire length, with the anchorages for the two car ropes at one end and for the two counterweight ropes at the other end, as shown in Fig. 29 (*c*). For the machine-"above" condition half of the drum is grooved right-hand and the other half left-hand with the anchorages for the car and counterweight ropes arranged as shown in Fig. 29 (*d*).

It will be appreciated that when a drum machine is installed "below" it is necessary for the diverting pulley to be arranged on a shaft of approximately the same length as the drum, so that the diverting pulley can move along the shaft as the ropes traverse the drum when being wound on and off it.

By arranging the drum grooving and the rope anchorages as shown in Fig. 29 (*c*) and (*d*), the same grooves are used for the car and counterweight ropes; as one set of ropes is unwound from one side of the drum the other set of ropes is wound on the other side of it. At least two turns of each rope are left on the drum always, so that the anchorages are relieved of any direct pull.

If the car or counterweight of a lift with a drum machine installed "below" were to meet an obstruction in the lift well when descending, the ropes would be unwound from the drum, leaving their grooves and falling on to the machine bedplate, and to guard against such a contingency a switch, known as a slack-rope switch, carrying a suitable apron extending the length of the drum, is fitted to the bedplate. With this arrangement the slack-rope switch would operate as soon as the ropes leave their grooves owing to their weight depressing the apron, and the opening of the switch would cause the power supply to the motor to be cut off and the brake applied.

When the machine is installed "above," this method of operating the slack-rope switch has to be modified, because the slackening of the rope would occur in the lift well, and the slack-rope switch is therefore fitted on the car and so connected to the ropes that in the event of their becoming slack the switch is opened.

An alternative method of operating the slack-rope switch is to furnish a shaft carried at its ends by weighted levers and provided with pulleys, which are held against the ropes by these weighted levers: the slackening of the ropes will cause the shaft to be displaced and thereby open the slack-rope switch.

**Geared Traction Machines.**

In the traction type of machine, the traction sheave is provided with the same number of grooves as there are ropes, and the friction between the ropes and the sheave is depended upon to transmit the necessary effort to raise the car or counterweight. Apart from the advantage that the size of the traction machine is independent of the rise of the car, another important feature of the traction type of drive is the inability of the machine to draw the car, or counterweight, into the overhead supporting steelwork, which is possible with the drum type of machine because the ropes are anchored to the drum. As soon as the car or counterweight strikes the buffers, the traction between the ropes and sheave is reduced, and any further rotation of the sheave will not raise the car or counterweight.

For goods lifts, where the loads are often heavy and a slower speed is of little consequence, internal spur gearing can be incorporated in the worm-geared machine. The spur gearing not only reduces the speed to enable a greater load to be raised for a given-size motor, but it brings the pressure on the worm gearing and worm thrust within the allowable pressures for a normal worm-geared machine.

Machines for service lifts are generally similar to those for passenger and goods lifts. Because of the relative smallness of such machines it is necessary to modify the design of the brake, but the principle of operation remains.

**Gearless Traction Machines.**

As previously mentioned, the gearless machine has its traction sheave and brake drum mounted direct

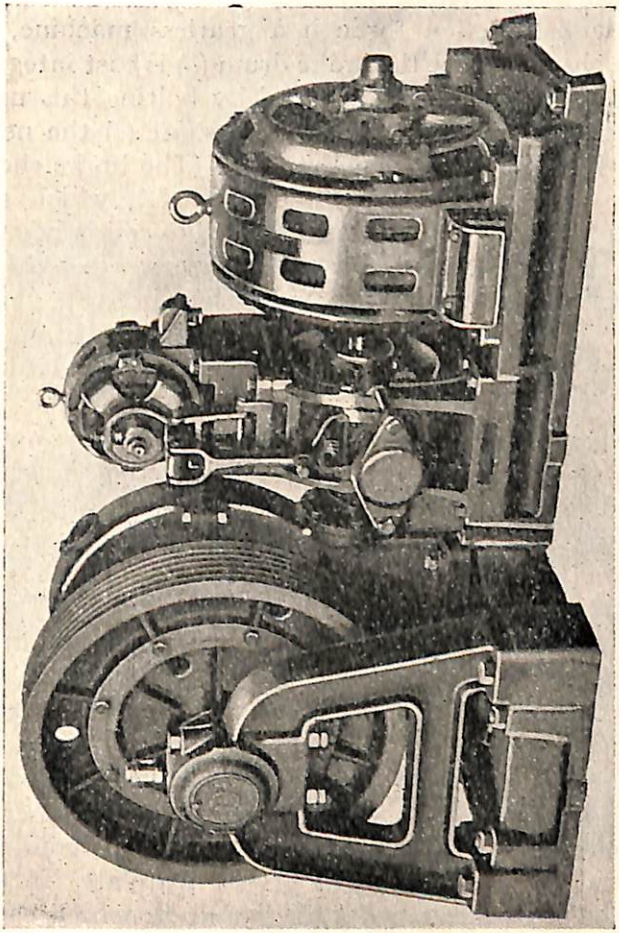


FIG. 30.—GEARED TRACTION-TYPE MACHINE.

on the armature shaft without any form of reduction gearing or thrust units, and thus vibration is eliminated and wear is negligible. Referring to Fig. 33, which shows a half-section through a gearless machine, it will be observed that the brake drum (*b*) is cast integral with the traction sheave (*t*), and by bolting this unit to a flange forged on the armature shaft (*s*) the need for keying these parts is eliminated. The brake shoes (*a*) are connected to the brake arms (*c*), which are operated by the levers (*l*), and the brake coil is housed in the casing (*d*) carried from the bearing pedestal (*p*). On the brake-coil casing is mounted a switch (*e*), which is opened by the brake levers (*l*) when the brake is released; the purposes of this switch will be described later.

It will be noticed that the motor itself is of orthodox design, the pole-pieces (*f*) being bolted to the yoke-ring (*g*) and excited by the shunt field windings (*h*). The armature laminations (*j*) are held between the end flanges (*m*) and are compressed under hydraulic pressure before being secured by the ring (*q*). These end flanges serve as a support for the armature windings (*n*) and are kept in position by the key (*k*), which is used to prevent the armature laminations from rotating on the shaft.

The commutator (*o*) is assembled on the hub (*y*), which is secured to the shaft by means of a number of setscrews, and the brush-gear (*v*) is carried from the yoke ring (*g*). At the ends of the bedplate (*u*) are mounted the bearing pedestals (*r* and *p*), which carry the bearing sleeves (*w*) lined with Babbitt metal in which the shaft rotates.

Owing to the absence of reduction gearing the

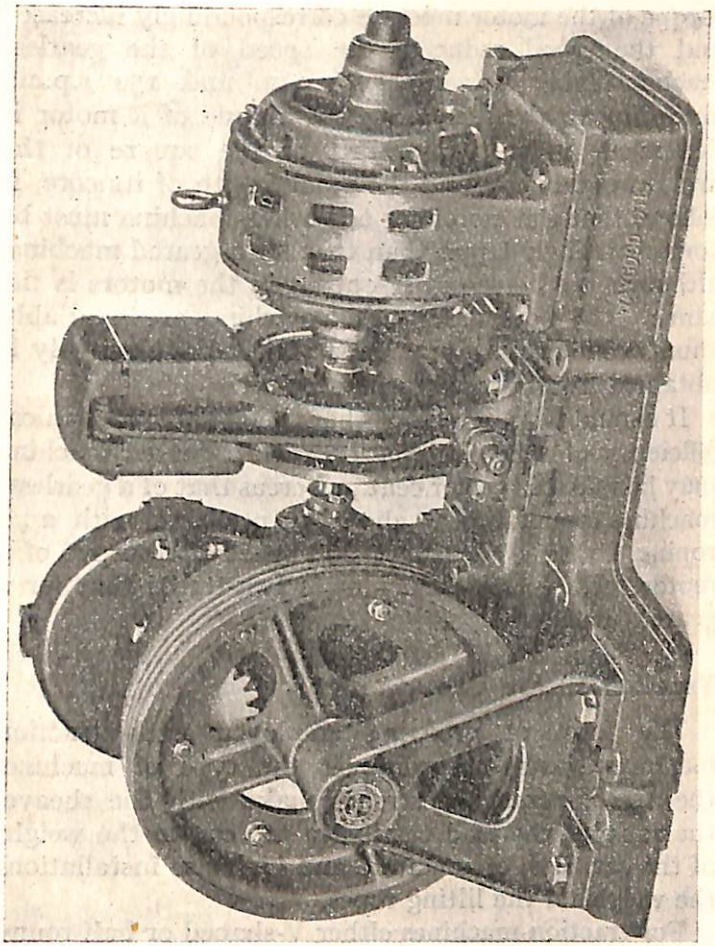


FIG. 31.
FOR HEAVY GOODS LIFTS.
Geared traction machine with internal spur gearing.

torque of the motor must be correspondingly increased and the speed reduced, the speed of the gearless machine lying between 50 r.p.m. and 150 r.p.m., according to the duty. As the torque of a motor is dependent upon the product of the square of the armature diameter and the axial length of its core, it follows that the motor for a gearless machine must be correspondingly larger than that for a geared machine, although the horse-power output of the motors is the same. The motors for gearless machines are invariably shunt wound, and the necessary D.C. power supply is obtained from a motor-generator set.

It should be pointed out that the overall mechanical efficiency of a lift installation with a geared machine may be taken as 50 per cent., whereas that of a gearless-machine installation is about 75 per cent. with 2 : 1 roping, so for a given load and speed the output of a motor for a gearless machine is two-thirds that for a geared machine.

**Traction-sheave Grooving.**

The form of grooving employed with traction machines varies according to the type of machine, the arc of contact the ropes make with the sheave, the ratio of the load carried in the car to the weight of the car, and, on medium- and high-rise installations the weight of the lifting ropes.

For traction machines either V-shaped or half-round undercut grooves as shown in Fig. 34 (*a*) and (*b*) respectively are employed; for gearless machines the half-round groove (*c*) is usually provided. It is well known that a V-groove has the effect of increasing the resistance to slipping, because the rope is supported

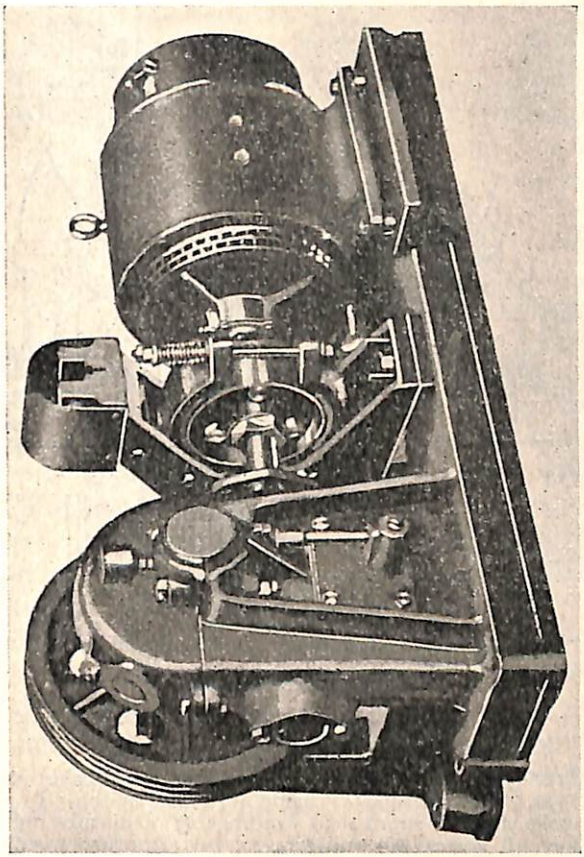


FIG. 32.—GEARED TRACTION MACHINE FOR SERVICE LIFT.

on two surfaces and the pressure on each side of the groove is greater than half the normal pressure on a half-round groove. The angle for V-grooves varies from 30 to 42 degrees.

**V-grooves.**

Referring to Fig. 35 (*a*), the pressure on one side

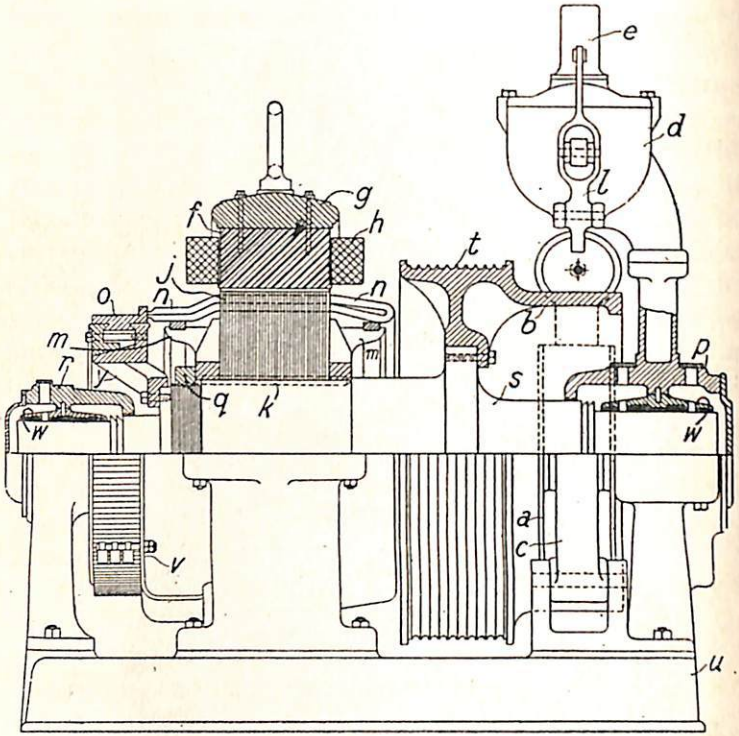



FIG. 33.—GEARLESS TRACTION MACHINE.

A half-section through typical machine: (*a*) brake shoes, (*b*) brake drum, (*c*) brake arms, (*d*) casing, (*e*) brake switch, (*f*) pole-pieces, (*g*) yoke ring, (*h*) shunt field windings, (*j*) armature laminations, (*k*) key, (*l*) levers, (*m*) end flanges, (*n*) armature windings, (*o*) commutator, (*p*) and (*r*) bearing pedestals, (*q*) ring, (*s*) armature shaft, (*t*) sheave, (*u*) bedplate, (*v*) brushgear, (*w*) bearing sleeve, (*y*) hub.

of the groove is $R = \dfrac{P}{\sin \dfrac{\alpha}{2}}$, and the resistance to slipping is therefore $2\mu R$, where $P$ is the normal vertical pressure, $\mu$ is the coefficient of friction, and $\alpha$

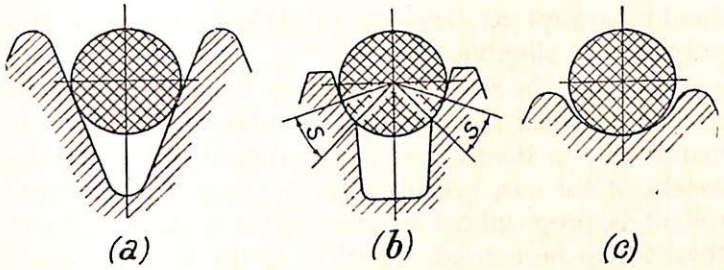



FIG. 34.—FORMS OF SHEAVE GROOVING EMPLOYED WITH TRACTION MACHINE.

is the angle of the groove. It therefore follows that the smaller the angle the greater will be the resistance to slipping, but the effect of the V-groove is to pinch the rope and thereby cause high internal stresses in that portion of the rope that is in contact with the sheave. Moreover, as soon as the groove wears to the shape of the rope the pinching, or wedging, effect is reduced, and consequently the resistance to slipping is reduced. For these reasons the use of the V-groove should be limited to slow-speed lifts that are not subject to heavy service.

Apart from the shape of the groove, the resistance to slipping is dependent upon the arc of contact the ropes make with the sheave. Referring to Fig. 35 (*b*), the tension in the ropes, due to the car and counterweight, is denoted by $T_1$ and $T_2$, $T_2$ being the greater, and the ratio of $T_1 : T_2$ may be expressed as $\frac{T_2}{T_1} = \varepsilon^{\theta\mu}$, where $\varepsilon$ is the base of Napierian logarithms, $\theta$ is the arc of contact in circular measure, and $\mu$ is the coefficient of friction between the ropes and the sheave. From this formula it will be seen that the arc of contact

should be kept as large as possible to increase the resistance to slipping.

Neglecting the weight of the ropes, the difference in tension between the car and counterweight ropes is mainly due to the ratio of the load to be raised to the weight of the car, because the weight of the counterweight is proportional to the weight of the car and the load to be carried. With a heavy car and comparatively light load, the ratio of $T_1 : T_2$ is less than with a light car and a comparatively heavy load, and care should therefore be taken to avoid the risk of slipping and consequent rope and sheave wear by having a light car with a heavy load. It will be realised that when rope compensation is not employed and an empty car is about to descend from the top floor, the weight of the lifting ropes has an adverse effect upon the $T_1 : T_2$ ratio. Moreover, the tension in the ropes is more than that due to the actual loads, because when starting a car upwards or stopping its descent, the forces necessary for acceleration and retardation must be included.

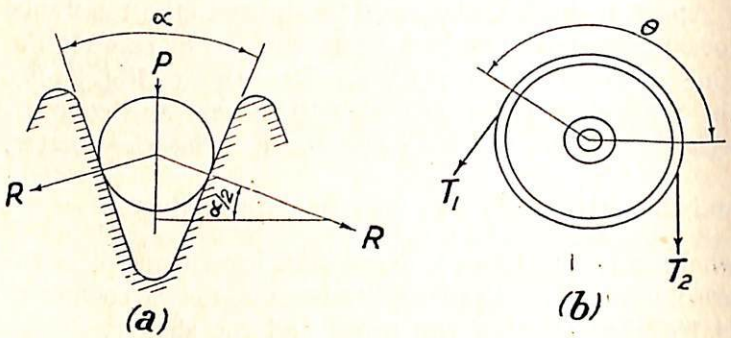



FIG. 35.—RESISTANCE TO SLIPPING OF ROPE IN GROOVE.

**Half-round Grooves.**

The objections to V-grooves have been largely overcome by the use of the half-round undercut groove shown in Fig. 34 (*b*), where it will be observed that the rope has two narrow rope seats (*s*) machined to the same diameter as the rope, which is therefore not subjected to the same pinching effect as with V-grooves. With a half-round undercut groove the resistance to slipping depends upon the width of the seat, which is governed by the width of the undercutting, and this undercutting allows the width of seat to remain almost constant as the groove wears. By reducing the width of the undercutting the rope seat is increased, enabling more load per rope to be carried; but the tractive effort is reduced, and the most advantageous width of rope seat therefore depends upon the several factors previously mentioned.

**Grooves for Gearless Machines.**

For gearless machines where the duty is heavy, half-round seats as shown in Fig. 34 (*c*) are used, and the radius of the groove is slightly larger than the radius of the rope. With a half-round seat the wear in the groove is negligible, but the reduced tractive effort of this type of groove is compensated by increasing the arc of contact to some angle approaching 360°, which is accomplished by employing a secondary sheave. As previously explained, the secondary sheave enables the ropes to be passed over the driving sheave a second time to increase the arc of contact.

It must be pointed out, however, that with traction drives the ropes slowly change their relative positions on the sheave as soon as the tension in the ropes on

one side of the sheave is different from that on the other side. This condition is known as rope creep, and it is caused by the increasing tension in the rope around the sheave from the light side to the heavy side, and, owing to the elasticity of the rope, the rope creeps along the groove as the sheave is rotating. Rope creep occurs in the direction towards the preponderance of load and is independent of the direction of rotation.

## CHAPTER III

# ELECTRO-MECHANICAL BRAKES AND MOTORS.

### Preliminary Considerations.

ALL electric lift machines are now provided with electro-mechanical brakes in which the retarding force is provided by compression springs and the brake shoes are released electro-magnetically. The older type band brake has been superseded by the solid-shoe type, because, apart from the more rigid construction that is possible with the modern type, the retarding torque of the band brake varies with the direction of rotation. It is necessary for a brake to stop the lift and to hold the loaded car at rest, and owing to the important functions of a brake it should be designed with a generous factor of safety. When stopping a lift the kinetic energy of all the moving parts must be absorbed; some of this energy, however, is absorbed in the friction of the lift, and with 2-speed A.C. motors and D.C. motors some of the energy is absorbed by dynamic braking. The formula for kinetic energy is $E = \frac{WV_2}{2g}$, where $E$ = kinetic energy in foot-pounds, $W$ = weight of the body in pounds, $V$ = velocity of the body in feet per second, $g$ = acceleration due to gravity in feet per second$^2$. This formula must be extended to ascertain the total kinetic energy of the lift, because not only are the car, counterweight, ropes, etc., moving but also the motor armature,

(*a*) Hinge, (*b*) brake shoes, (*c*) magnet coil, (*e*) screws, (*f*) brake frame, (*g*) friction lining, (*l*) adjustable links, (*n*) nuts, (*p*) mild-steel cores, (*r*) rod, (*s*) compression springs, (*t*) air gap.

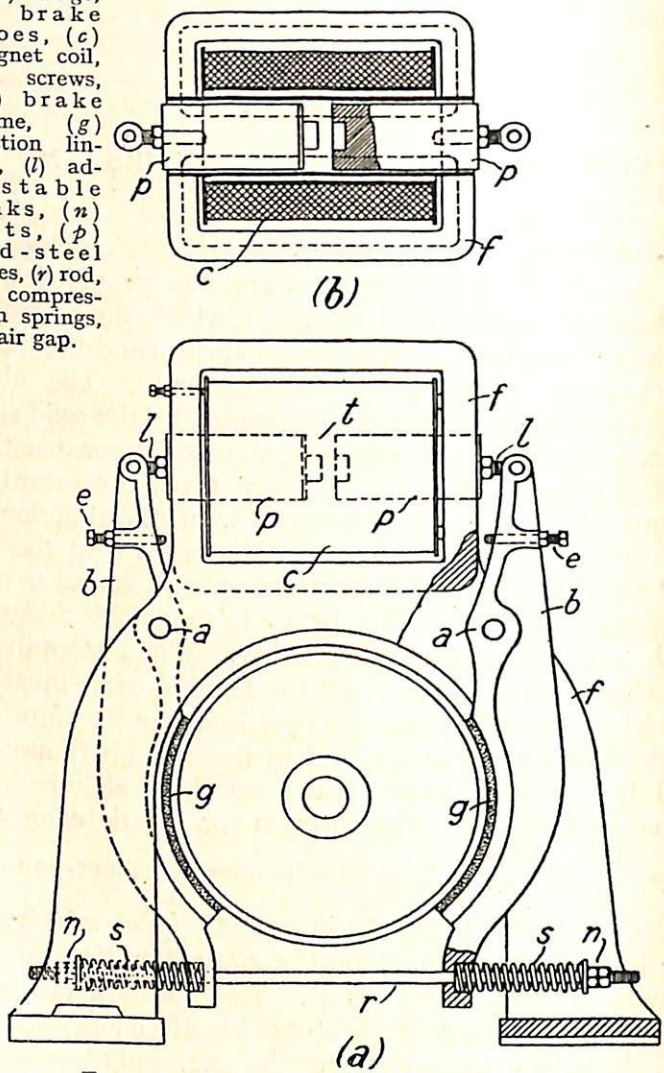



FIG. 36.—TYPICAL DIRECT-CURRENT BRAKE.
The magnetic circuit is shown in (*b*).

brake drum, driving sheave, worm, and worm wheel. The kinetic energy of the rotating parts of a geared machine for a car speed of 200 ft. per minute is more than 75 per cent. of the total kinetic energy of the lift; for lower car speeds it is higher. Whilst a brake must operate with certainty, it must not be harsh in application and cause discomfort to the passengers and set up unnecessarily high stresses in the lift equipment.

**Direct-current Brakes.**

Details in the design of brakes vary considerably, but the principle of using two brake shoes and a single electro-magnet for D.C. brakes has become usual practice, and a typical brake is shown in Fig. 36 (*a*), where it will be observed that the brake frame (*f*) not only carries the brake shoes (*b*) and the magnet coil (*c*), but its upper portion forms part of the magnetic circuit. The brake shoes (*b*) are hinged to the frame at (*a*) with their upper ends connected to the magnet cores, or plungers, by the adjustable links (*l*). Through their lower ends passes a rod (*r*) which serves to connect the two compression springs (*s*) to the brake shoes and at the same time equalise the pressure between the brake shoes and the brake drum. By employing compression springs the risk of spring failure is reduced considerably, because should a spring fracture, the remaining turns of the spring would exert sufficient force to stop and hold the car.

It is necessary to adjust the retarding force for stopping a lift to suit the conditions peculiar to each installation, and this is accomplished by altering the tension of the compression springs (*s*) by means of the nuts (*n*). The clearance between the brake linings

and the brake drum when the brake is released is obtained by adjusting the screws (*e*), and this clearance should be kept down to a minimum, so that the brake shoes are applied quickly but without slam. Each brake shoe is lined with an incombustible friction lining (*g*), such as one of the die-pressed asbestos-fabric products.

By means of the adjustable links (*l*) the air gap (*t*) can be so regulated that when the brake shoes are released the magnet cores do not meet. The purpose of leaving an air gap is twofold. Firstly, by preventing the cores from meeting, noise is eliminated; and secondly, an air gap prevents the cores from being held together by residual magnetism when the brake-coil circuit is opened. It will be realised that if the cores were held together the results might be serious, and it is therefore customary to face one core with a non-magnetic material, such as brass, to ensure that the cores will be separated by a permanent air gap should the cores meet from any cause.

Referring to Fig. 36 (*b*), the magnetic circuit is formed by the cast-iron magnet frame (*f*) and the mild-steel cores (*p*), and the magnetic flux takes the two paths indicated by the dotted lines. It will be observed that the inner ends of the cores are provided with male and female ends, which take the form of a projection and a corresponding recess slightly larger in diameter than the projection. The effect of so shaping the ends is to reduce the effective air gap without reducing the stroke of the cores, and by so reducing the air gap the initial pull is greater for a given number of ampere-turns than it would be with flat-ended cores. Moreover, when the projection enters the recess, the

magnetic flux acts radially on the core ends at right angles to its normal direction and so produces a magnetic cushion effect.

By connecting a resister permanently in parallel with the brake-coil winding, not only is the induced e.m.f. prevented from rising to an excessive value when the impressed e.m.f. is removed, but it allows this induced current to circulate through the coil in the same direction as that due to the applied voltage, and, owing to the dying away of the current in accordance with Helmholtz's law, the magnetic flux is gradually reduced and consequently the brake shoes are applied to the brake drum without slam.

**Alternating-current Brakes.**

With D.C. motors it is possible to take advantage of the dynamic braking that takes place when stopping the armature. Similarly, when a 2-speed, A.C. pole-changing motor is running at its top speed and its slow-speed winding is energised and its high-speed winding de-energised, the speed of the motor is higher than the synchronous speed of the slow-speed winding and a braking torque is therefore exerted; the value of this braking torque will depend upon the torque the motor is designed to develop at slow speed. With single-speed A.C. motors, however, no dynamic braking exists, and it is therefore necessary to make the brakes for single-speed A.C. motors correspondingly larger.

In the design of A.C. brakes many difficulties have been encountered in endeavouring to make them quiet and smooth in operation. Because of the inherent pulsating magnetic flux that is set up in the cores of a single-phase A.C. electro-magnet, the cores separate

(*a*) Operating arms, (*b*) fulcrum, (*c*) laminated cores, (*d*) magnet frame, (*e*) brake shoes, (*f*) fulcrums, (*l*) links, (*n*) nuts, (*s*) springs, (*t*) shading coils, (*v*) piston, (*w*) brake coil, (*y*) air gap.

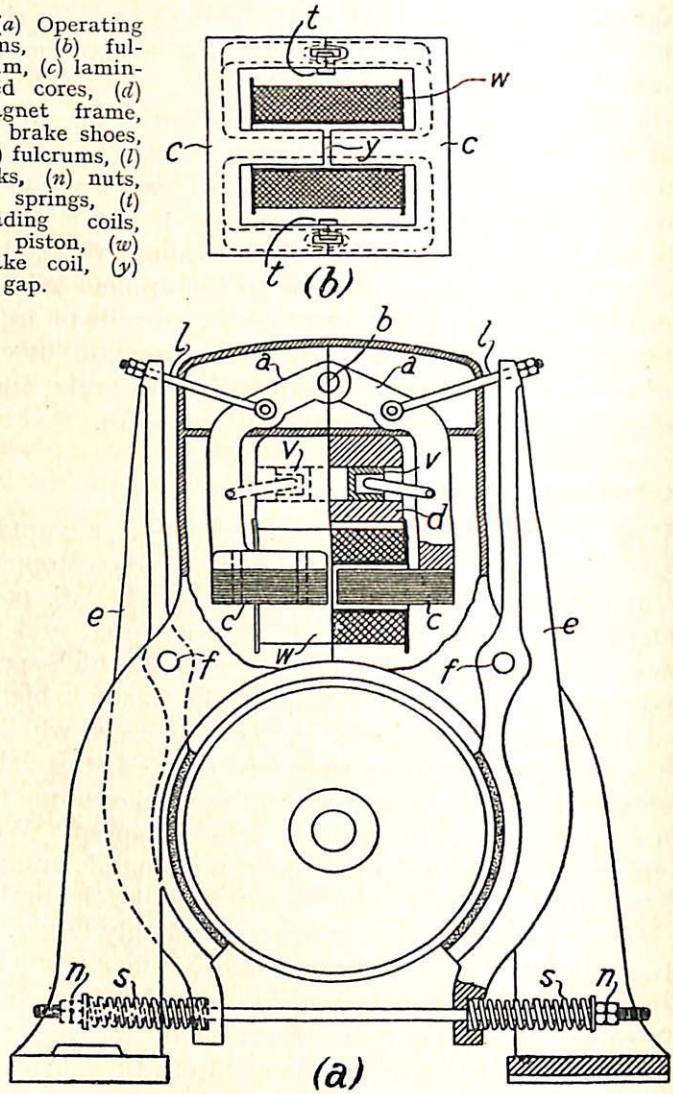



FIG. 37.—SINGLE-PHASE BRAKE.

each time the flux passes through zero and then rapidly come together as the flux increases to its maximum value, and thus violent chattering occurs. This difficulty has been overcome by providing the cores with a shading coil, which has the effect of producing a secondary flux while the main flux is passing through zero, and thus a continuous pull is secured.

The second difficulty lies in the fact that the magnetic pull alternates from a minimum to a maximum value and the load on the cores must therefore not exceed the minimum pull, with the result that the average pull is considerably in excess of the applied load and the cores are pulled together with an objectionable slam.

**Single-phase Brake.**

Various designs have been evolved to overcome these difficulties, and one type of single-phase brake that incorporates various devices to overcome the objections just cited is shown in Fig. 37 (*a*) and (*b*). Referring to Fig. 37 (*a*), it will be noticed that the general arrangement of the brake is similar to the D.C. brake previously described, but the brake coil, with its magnet cores and operating arms, is suitably housed to enable these parts to be immersed in oil. In order to reduce the eddy-current losses the magnet cores are laminated, and by using E-shaped laminations the coil winding can be arranged around the central limb and the shading coils inserted in the outer limbs, as shown in Fig. 37 (*b*). With A.C. electro-magnets it is essential that the cores make as perfect contact as is practicable when the coil is energised so that the reluctance of the iron circuit is low and the inductance

relatively high; the higher the inductance the lower the operating current. Conversely, if the cores do not meet the current will be high, and in many instances it will be sufficiently high to cause the coil to burn out, because the current taken by such a magnet may be as much as five times as great when the cores are open as when they are closed. Furthermore, the quality of the workmanship must be high to ensure that the cores make even contact to avoid chatter and noisy operation.

The laminated cores (*c*) are bolted to the operating arms (*a*), which have a common fulcrum (*b*) and are connected to the brake shoes (*e*) by means of the adjustable links (*l*). As it is imperative that the magnet cores meet, the amount of movement of the brake shoes is determined by the adjustment of the links (*l*). When the brake coil (*w*) is energised the cores (*c*) are pulled together, causing the brake shoes (*e*) to move on their fulcrums (*f*) and so release the brake drum. The tension on the brake drum is furnished by the springs (*s*), and it is adjusted by means of the nuts (*n*).

Referring to Fig. 37 (*b*), which shows the laminated cores (*c*) closed and the main paths of the magnetic flux, it will be observed that the outer limbs are slotted to accommodate the shading coils (*t*), and the section of the core within the shading coil is known as the shaded pole. The current induced into the shading coil by the main flux is almost opposite in phase to the current in the brake coil; consequently the flux due to the shading coil is out of phase with the main flux, and it therefore follows that when the main flux is passing through zero the secondary flux in the shaded

pole is approaching a maximum value, and a continuous magnetic pull is therefore maintained.

As the laminations for the cores are made from alloyed steel, the remanence—that is, the amount of magnetism remaining in the cores after the coil winding is de-energised—is inherently small, and the risk of the cores being held together by residual magnetism is therefore low, but by so arranging the central limbs of the magnet cores that a small air gap (*y*) exists when the cores are closed, the brake is prevented from being held off by residual magnetism.

To prevent the magnet cores from slamming when the coil is energised, each operating arm (*a*) is connected to a piston (*v*) which moves in a cylinder in the magnet frame (*d*), and as the magnet frame, together with its cores and coil winding, is immersed in transformer oil, a dashpot action is thereby provided and the movement of the cores is retarded. The cylinder is furnished with a variable port through which the flow of oil can be regulated to give retardation to prevent harshness in operation, both when the brake shoes are released and applied.

**Polyphase Brakes.**

For heavy-duty lifts it was customary to employ polyphase brakes in place of single-phase, because with the latter the retarding torque increased at a greater rate than their size and the current for operating the brake was taken from more than one phase. By using more than one phase of a polyphase power supply, advantage can be taken of the fact that the currents in the different phases are out of phase and consequently the flux in the cores is never zero. Moreover, the

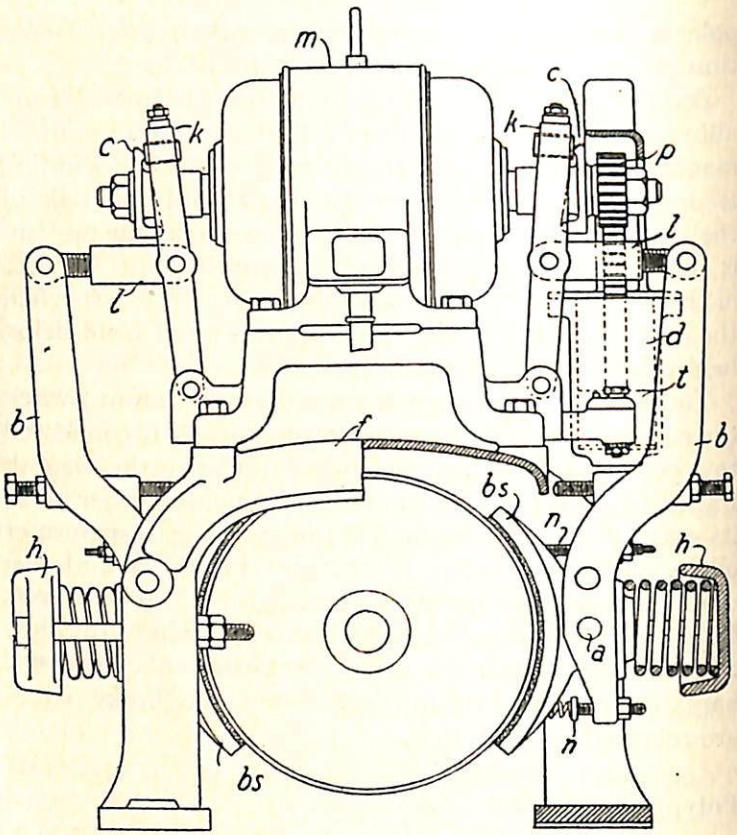



FIG. 38.—APPLICATION OF TORQUE MOTORS FOR OPERATING BRAKES.

KEY TO LETTERING:

(*a*) Fulcrums, (*b*) brake-shoe levers, (*bs*) brake shoes, (*c*) cams, (*d*) air dashpot, (*f*) brake frame, (*h*) spring housings, (*k*) levers, (*l*) links, (*m*) torque motor, (*n*) adjustable stops, (*p*) pinion, (*t*) piston.

minimum flux is relatively greater than the minimum flux of a single-phase brake with a shading coil.

Such brake magnets, however, have been superseded by small induction motors capable of being stalled.

These motors, usually known as torque motors, are high-resistance squirrel-cage motors of many poles, designed to develop a high torque with small temperature rise and consume comparatively little current. Being quiet in operation, they are a great advance over polyphase magnets.

**Application of Torque Motors for operating Brakes.**

The application of torque motors for operating brakes takes different forms; with the method shown diagrammatically in Fig. 38, the torque motor (*m*) is mounted on the brake frame (*f*), and at each end of the rotor shaft is fitted a cam (*c*) which engages with a ball race mounted on the lever (*k*). These levers are connected to the brake-shoe levers (*b*) by means of the links (*l*), and thus the rotary motion of the rotor is changed to a straight-line motion for releasing the brake shoes. When the motor is energised, the cams are turned about one-third of a revolution to release the brake shoes, and in doing so rotate the pinion (*p*), which raises a rack connected to the piston (*t*) in the air dashpot (*d*); the weight of the piston (*t*) is sufficient to return the rotor to its normal position when the motor is disconnected from the power supply. A dashpot is provided with this motor-operated brake for the same purpose as for magnet-operated brake, namely, to prevent harshness in the release and application of the brake shoes. Owing to the heavier duties for which these brakes are employed the brake shoes (*bs*) are separate components and are secured to the brake-shoe levers at the fulcrums (*a*). Whilst the brake shoes are free to move independently of the brake-shoe levers, they are restricted in their

movement by the adjustable stops (*n*), the lower of which are spring loaded.

Reverting to Fig. 30, which shows a geared traction machine with a motor-operated brake, it will be

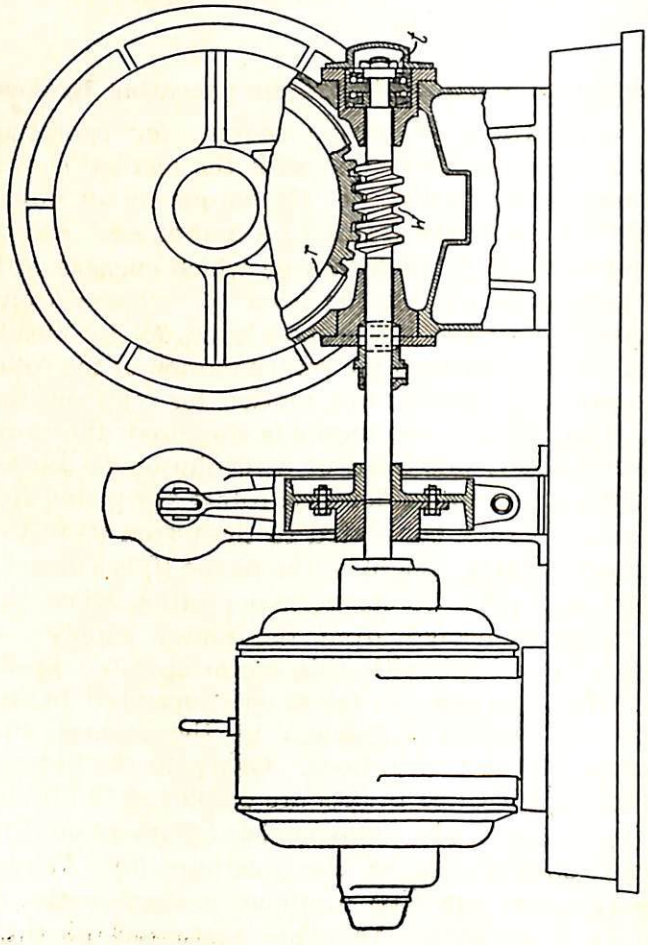


FIG. 39A.—WORM REDUCTION GEARING FOR LIFT MACHINES.
(*w*) Worm, (*r*) worm-wheel rim, (*t*) thrust bearing, of double-ball type.

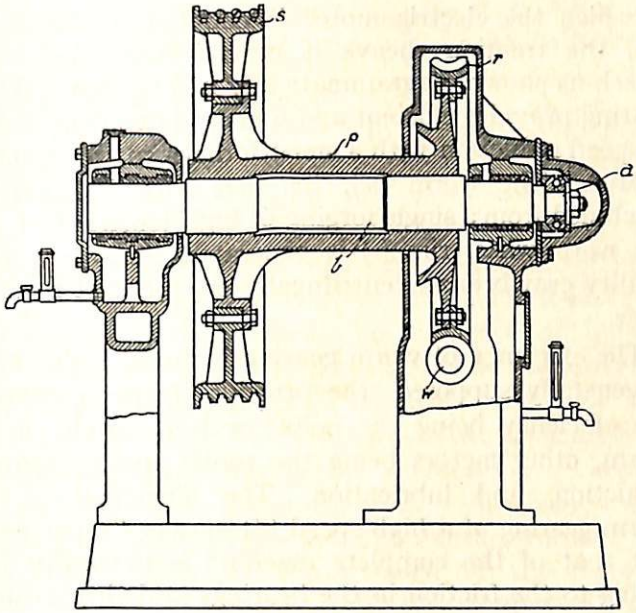



FIG. 39B.—WORM-WHEEL THRUST BEARING FOR HEAVY DUTIES.

(*a*) Ball thrust bearing, (*b*) shaft, (*p*) spider, (*r*) worm-wheel rim, (*s*) traction sheave, (*w*) worm.

appreciated that it is impracticable to fit the springs for applying the brake shoes in the same manner as employed for the smaller brakes previously described, and the springs are therefore arranged between the sides of the brake frame as shown in Fig. 38, and the tension is adjusted by means of the bolts holding the spring housings (*h*).

**Worm Reduction Gearing.**

All things considered, the most satisfactory form of reduction gearing for lift machines is worm gearing

in which the electric motor is coupled to the worm and the traction sheave is driven from the worm wheel, as shown diagrammatically in Fig. 39A. Worm gearing provides efficient and a very convenient means of speed reduction with a smooth drive to the traction sheave. The worm (*w*), together with its shaft, is machined from a single forging of high-tensile steel, and the worm-wheel rim (*r*) is generated from a special-quality gear bronze, centrifugally or chill cast to resist wear.

The efficiency of worm gearing is much higher than is generally supposed; the principal factor governing the efficiency being the helix, or lead, angle of the worm, other factors being the tooth profile, ratio of reduction, and lubrication. The efficiency of the worm gearing of a high-speed lift is over 85 per cent., but that of the complete machine is naturally less, owing to the friction in the bearings and thrust units. Moreover, it is often, but nevertheless erroneously, believed that all worm gears are self-locking or self-sustaining, that is, it is not possible for a force applied to the worm wheel to turn the worm. Apart from the friction in the bearings and other parts of the equipment, the efficiency of the gearing must be less than 50 per cent. before a worm gear is self-sustaining, and an efficiency as low as this for the majority of lift gearing is the exception and not the rule. For this reason it may be mentioned parenthetically that before dismantling or making a major adjustment to a lift gear or brake, the car should be empty and the counterweight should be landed on its buffers.

As the efficiency of a machine is an important factor in the overall mechanical efficiency of the lift, it will

be appreciated that it affects the size of the lift motor and the power consumption, as will be shown later.

**Thrust Units.**

Referring to Fig. 39A, it will be realised that any difference in tension in the car and counterweight ropes will tend to rotate the worm wheel and so produce a horizontal thrust in the worm shaft; the direction of this thrust will naturally depend upon the direction in which the out-of-balance load tends to rotate the worm wheel. These thrusts are severe, and suitable thrust bearings must therefore be provided. The thrust bearing (*t*) is of the double-ball type, and by arranging it at one end of the worm shaft it is possible to carry out thrust inspections or repairs without removing the worm shaft. Moreover, owing to the helix angle of the gearing, another thrust is set up in the shaft of the worm wheel, but this thrust is considerably less than that in the worm shaft, and for heavier duties a ball thrust bearing (*a*), as shown in Fig. 39B, is employed, but for lighter duties marine thrust bearings will suffice.

It will be observed in Fig. 39B that the traction sheave (*s*) is driven direct from the worm wheel through a spider (*p*) which is pressed on to the mainshaft; the sheave and worm rim are bolted to this spider, thus relieving the shaft (*b*) of almost all torsional stresses, and the use of keys for securing these parts is rendered unnecessary.

## LIFT MOTORS

**Determination of Motor Output.**

As already explained, the size of a lift motor is dependent not only upon the duty of the lift, but also

upon its overall mechanical efficiency, and the most important factor in this efficiency is that of the machine. The efficiency of a lift increases with its size, so for a small service lift it is usual to allow about 30 per cent. and for the largest high-speed lifts with geared machines this value can be as high as 60 per cent. When a machine with spur gearing is employed, a reduction in efficiency of 5 per cent. should be allowed, and similarly, with abnormally slow car speeds, where the helix angle of the worm is small, the efficiency will be lower than normal. With gearless lifts, where frictional losses due to gearing, thrust units, and additional bearings are eliminated, the efficiency may be taken as 75 per cent. For lifts roped 2 : 1 a further reduction of 2 per cent. should be included.

As a lift is provided with a counterweight to counterbalance the car and a part of the load, the motor has to raise only the out-of-balance load. Except for peak periods lift cars are seldom loaded more than three-quarters of their contract load, and it is therefore economical to balance the weight of the car plus 40 per cent. of contract load; this percentage of overbalance is adjusted in special instances to reduce the ratio of the tension of the car and counterweight ropes, and for gearless machines, where traffic conditions are usually heavy, the overbalance is increased to 42½ per cent., but in no instance is it made more than 50 per cent. of contract load.

Having ascertained the overall mechanical efficiency the percentage of overbalance, and knowing the contract load and car speed, the output of the motor can be calculated as follows—

$$\text{Horse-power} = \frac{100 - B}{100} \times \frac{L \times S}{33{,}000} \times \frac{100}{e}$$

where $B$ = percentage overbalance
$L$ = contract load in pounds
$S$ = car speed in feet per minute
$e$ = percentage mechanical efficiency.

If, however, an unbalanced lift is required, the size of the machine and motor must be considerably increased, because the car as well as the unbalanced contract load has to be raised, and the output of the motor then becomes—

$$\text{Horse-power} = \frac{C + L}{33{,}000} \times S \times \frac{100}{e}$$

where $C$ = weight of car in pounds
$L$ = contract load in pounds
$S$ = car speed in feet per minute
$e$ = percentage mechanical efficiency.

Assume that a load of 900 lb. is to be raised at a speed of 110 ft. per minute, the overbalance being 40 per cent. and the efficiency 45 per cent.

$$\text{Horse-power} = \frac{100 - 40}{100} \times \frac{900 \times 110}{33{,}000} = \frac{100}{45}$$
$$= 4 \text{ h.p.}$$

If this load were to be raised without being counterbalanced and the car weighed 855 lb., the output of the motor would have to be—

$$\text{Horse-power} = \frac{855 + 900}{33{,}000} \times \frac{110 \times 100}{45}$$
$$= 13 \text{ h.p.}$$

**Motor Speeds.**

It is a well-known fact that slow-speed motors for a given output are larger, and therefore more expensive, than high-speed motors; this is especially true for small motors. The speeds of lift motors for geared

machines therefore vary from about 1,500 r.p.m. for service lifts to 600 r.p.m. for the largest machines. Having decided upon the diameter of the traction sheave and the motor speed, it is a simple matter to ascertain the ratio of the reduction gearing to give the required car speed. Afternatively, the sheave diameter being known, the motor speed to give the desired car speed with a given gear ratio and 1 : 1 roping can be ascertained as follows—

$$\text{Motor r.p.m.} = \frac{S \times R}{D \times \pi}$$

where $S$ = car speed in feet per minute
$R$ = gear ratio
$D$ = diameter of sheave in feet.

It should be explained, however, that in practice the motor speed is not necessarily decreased with increased motor output, because the most satisfactory combination of traction-sheave diameter, gear ratio, and motor speed has to be employed to give the required car speed. Moreover, with A.C. induction motors the selection of speed is inherently limited by the periodicity of the power supply and the number of poles in the motor.

With a 50-cycle power supply the range of synchronous speeds of induction motors normally used is limited to 1,500 r.p.m. for a 4-pole motor, 1,000 r.p.m. for a 6-pole motor, and 750 r.p.m. for an 8-pole motor; full-load speed is naturally less than the synchronous speed. For purposes that will be explained later, special 2-speed induction motors having two stator windings are employed to give two different speeds, and the slow-speed winding is wound for 48 poles to give a synchronous speed of 125 r.p.m.

**Starting Torque.**

As a lift motor is called upon to start against full load and give a satisfactory rate of acceleration, it must develop considerably more than full-load torque at starting. It is usual to allow not less than twice full-load torque for starting, and with A.C. motors the torque is proportional to the square of the voltage, so that any drop in voltage when starting causes a comparativeiy large decrease in torque, but by allowing a starting torque of twice full-load running torque, any slight drop in voltage is of small consequence.

**Direct-current Motors.**

Early geared machines were provided with shunt-wound D.C. motors, but the objection to these motors was their inability to exert the necessary starting torque to give satisfactory acceleration without taking a comparatively high starting current. This objection was overcome by the substitution of compound-wound motors, but the speed of such motors varies with the load. Moreover, the demand for higher car speeds necessitated lower gear ratios, and the helix angle of the ratio gearing became greater than the friction angle, consequently the gearing, as previously explained, was not self-sustaining, which resulted in a loaded car descending, or an empty car ascending, to drive the motor above normal speed and so cause it to function as a generator and so deliver power to the mains.

Referring to the wiring diagram in Fig. 40 (*a*), which shows the direction of the currents in the various circuits of a compound-wound motor, it will be observed that the current in the shunt and series field windings

is in the same direction, but with a generator, although the direction of rotation of the armature is the same, the current in the series field winding is reversed and opposes the shunt field, causing a reduction in the magnetic flux which, in turn, further increases the speed.

By switching the series field winding out of circuit after the starting resistance has been short-circuited, the two objections just cited, namely, the speed variations with different loads and the excessive speed due to reversed polarity of the series field winding, are overcome.

Modern D.C. lift motors have a comparatively low starting current, owing to the heavy compounding; twice full-load torque is developed with about one and one-third times full-load running current.

**Speed Control of D.C. Motors.**

Speed control of D.C. motors is readily secured by varying the strength of the motor field; with a motor designed for 2-speed operation, the slower speed is obtained by connecting the shunt field winding across

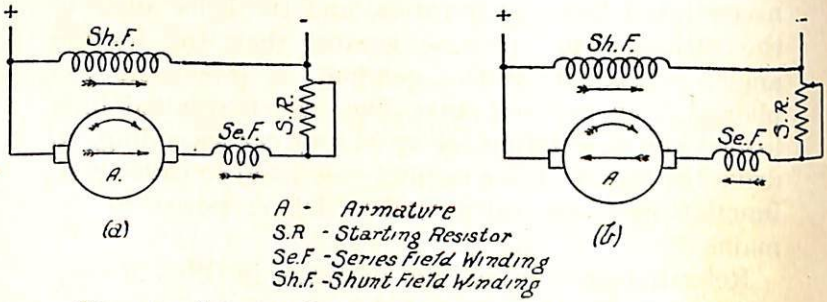



FIG. 40.—SHOWING DIRECTION OF CURRENTS IN COMPOUND-WOUND D.C. MOTOR.

(*a*) When functioning as motor. (*b*) When functioning as generator.

the power supply, and by inserting a resistor in series with the shunt field winding the magnetic field is weakened, and the motor then runs at its higher speed. This method of speed control is known as field regulation, and it enables the motor to run at either of its speeds with very small variations in speed from no load to full load.

It is of interest to mention that such motors are constant-output motors; that is, at slow speed they develop more torque than at high speed, and it is their higher speed and corresponding torque upon which the contract load and speed of the lift are based. At times advantage is taken of such motors for dual duty; that is, by employing, for example, a 2:1 speed-range motor, it is possible to raise twice the normal load at half the usual speed, but it is necessary to increase the weight of the counterweight to suit the increased load in the car.

It should be noted that whilst shunt-regulated motors are constant-output, or constant horse-power machines, variable-voltage controlled motors, however, are constant-torque machines, and if a dual duty as just described is required on a variable-voltage lift installation it is therefore necessary to design the lift motor for 2-speed operation by shunt field regulation as well as for variable-voltage speed control.

By making the inductance of the shunt field winding relatively high the time-constant of the field is increased, and this causes the change in magnetic flux to lag behind the change in current in the field winding when passing from high to slow speed, or, alternatively, from slow to high speed, and thus acceleration or retardation is smooth and continuous.

As lift motors must of necessity be of the reversible type, the brushes must be set on the neutral axis, and to ensure that the motor will operate in either direction of rotation without sparking at the brushes, interpoles are provided. The interpoles are fitted between the main poles, and as their coil windings are connected in series with the armature, their magnetising flux increases with load, and as they neutralise the field in the commutating zone, commutation is effected without sparking.

Another method of speed control is by inserting a resistor in series with the armature and another resistor in parallel with it, as shown in Fig. 41. These resistors have the effect of reducing the voltage across the armature and so reducing the speed, but as the voltage across the armature must vary with the changes in load it follows that speed will vary with the load and so make accurate floor stopping difficult to obtain. Owing to the losses in the series and parallel resistors with this arrangement for obtaining a slow speed, the power consumption is increased. For these reasons the use of series-parallel resistors for slowing is not to be recommended for heavy duties.

**Alternating-current Motors.**

For many years single-speed lifts operating on A.C. power supply had slip-ring motors, but the growing demand for higher car speeds created the need for 2-speed A.C. motors, and many difficulties were experienced in an endeavour to produce a satisfactory 2-speed motor with comparatively simple 2-speed switchgear. The difficulty was solved by making a special form of pole-changing squirrel-cage motor for

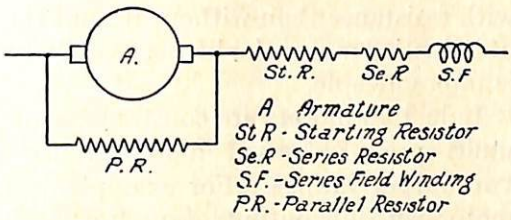



FIG. 41. SPEED CONTROL OF D.C. MOTOR BY USE OF SERIES-PARALLEL RESISTORS.

2-speed operation. These motors have relatively high-resistance rotors, and consequently the starting current is much lower than the usual general-purpose squirrel-cage motor; moreover, as they have only two stator windings, corresponding to the two operating speeds, the controlling switchgear becomes relatively simple.

Other types of 2-speed A.C. machines are in use, but their cost is much higher. In fact, for all 2-speed duties except the smaller ones serious consideration should be given to variable-voltage control, which gives results far above those obtainable with any other form of multi-speed control.

An advantage of the high-torque squirrel-cage motor over the wound-rotor type is that the moment of inertia is lower for the same output; consequently less power is required for acceleration and less power is wasted in braking.

At this juncture it may be mentioned that the speed of an induction motor for lift service cannot be reduced satisfactorily by the use of series resistors in the rotor circuit. Whilst it is possible to decrease the speed by this means when the motor is fully loaded, the speed at no load would be almost the same as full speed, regardless of the series resistor. With an overhauling load, however, the speed would be much higher than synchronous speed; in fact, the speed would be higher

with resistance than without it, and thus speed control of induction motors for lift services by means of resistors is impracticable.

Induction motors are constant-torque machines, and multi-speed induction motors must therefore have two output ratings. For example, a 3:1 speed-range motor with an output of 12 h.p. at its higher speed would be rated at 4 h.p. for its lower speed, and such motors cannot be employed for dual duties as described under Direct-current Motors.

**Single-phase Motors.**

At times one is reluctantly compelled to use a single-phase supply, which necessitates the provision of motors specially designed to give satisfactory torque and speed regulation. For many years repulsion and repulsion-induction motors were employed; the former type gives ample starting torque, but it is necessary to provide means for moving the brushes as the motor accelerates in order to improve the running torque and speed regulation. The repulsion-induction motor develops the high starting torque that is characteristic of a repulsion motor, and the running torque and speed regulation are similar to those of an induction motor, but to make the motor run as an induction motor it is necessary to short-circuit the commutator segments. Such motors, however, are inherently expensive. One type of motor was eventually developed which possessed all the advantages of its predecessor.

In this type of motor, the need for short-circuiting devices was eliminated. The rotor has two distinct windings, the outer winding being similar to that of a D.C. armature and connected to a commutator, the

inner winding being of the squirrel-cage type. During starting, the commutator winding only is embraced by the stator flux, and as the motor accelerates, the reactance of the squirrel-cage winding decreases and the magnetic flux then embraces this inner winding, and close speed regulation is thereby ensured; the transition from repulsion starting to induction running is quite gradual.

Another advance in single-phase motor design is the condenser motor. The stator has two windings, one of which is connected direct to the power supply and the other is connected to it through a condenser, which has the effect of producing a phase-displacement between the two windings. After the motor has accelerated, the condenser capacity is reduced by suitable switching, and thus a high starting torque and high power factor are secured without the use of a commutator and its brushes.

**Self-levelling Machines.**

With a view to ensuring that the car stops level with a landing, a self-levelling machine was developed. Reference to Fig. 42 will show that the machine has two sets of worm reduction gearing, two motors, a brake, and also a revolving brake, which couples the two machines together during the levelling operation and when the lift is at rest. The main motor with its gearing drives the car in the usual manner, with the brake shoes held clear of the revolving brake drum, but if the car should stop short or pass a floor within a distance of about 12 in., the levelling machine is coupled to the main machine by means of the revolving brake, and by energising the auxiliary levelling motor

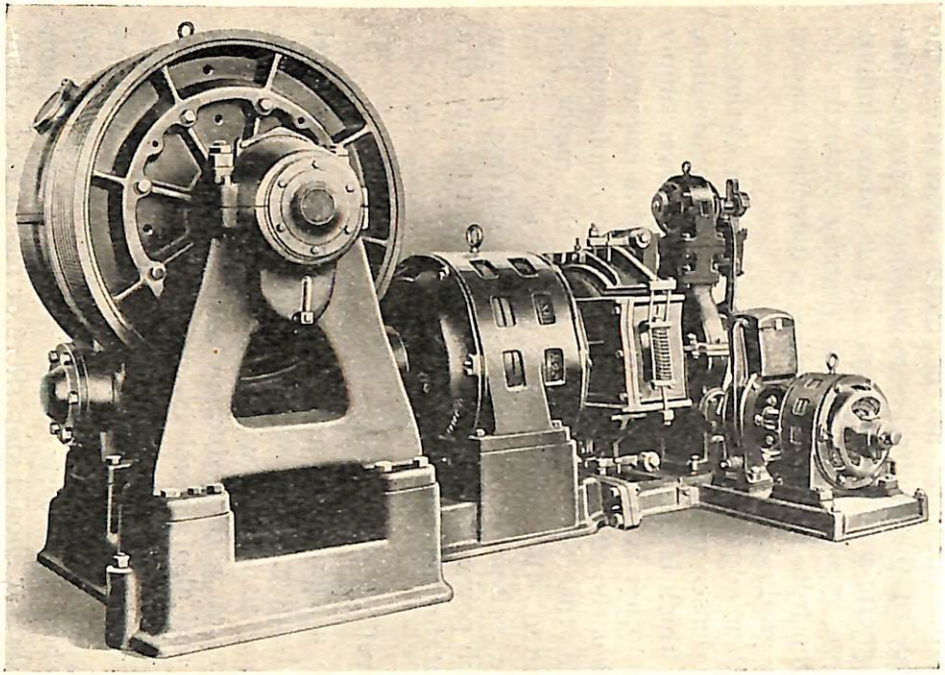


FIG. 42.—SELF-LEVELLING MACHINE.

This has two sets of worm reduction gearing, two motors, a brake, and also a revolving brake, which couples the two machines together during the levelling operation and when the lift is at rest.

and its brake the car is raised or lowered to floor-level. Such machines are available for D.C. and A.C. power supplies, and the method of operating these machines will be described later.

It will be appreciated that the revolving brake has two functions to perform: firstly, when the car stops level with the floor it serves as a normal brake; and secondly, when the levelling machine operates it couples the two machines and revolves. Owing to the worm gearing of both machines being in series the total gear ratio is very high, and the car therefore travels at a very slow speed, usually one-tenth of its normal speed when being levelled to a floor.

**The Revolving Brake.**

Referring to Fig. 43, which shows diagrammatically the revolving brake, it will be noticed that the brake shoes (*a*) and their levers (*b*) are supported by the revolving frame (*c*), which is carried at one end by a bearing (*d*) mounted on the main motor and at the other end by the levelling machine. Attached to this frame is the worm rim (*e*) of the levelling gear, so that when the brake shoes (*a*) are applied to the coupling (*f*), which is keyed to the main motor shaft, power is transmitted to the main machine when the levelling machine is operating. When the main motor is energised the brake coil (*g*) is also energised, causing the plunger (*h*) to move the crank lever (*k*) and so force the thrust rod (*l*) against the actuating levers (*m*) to release the brake shoes. These brake shoes are held against the coupling by means of the compression spring (*n*). For A.C. power supplies a torque motor of the type as described for motor-operated brakes is

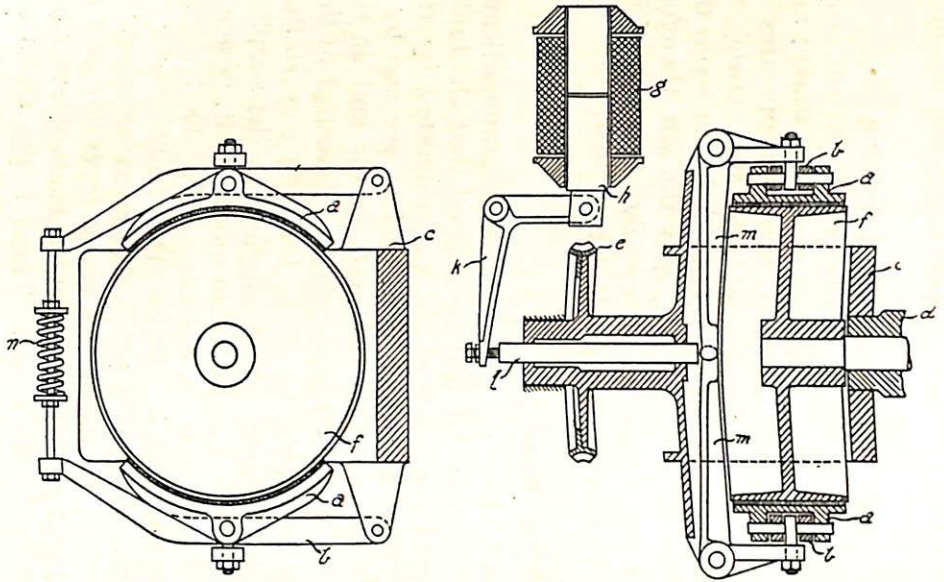



FIG. 43.—THE REVOLVING BRAKE.

(*a*) Brake shoes, (*b*) levers, (*c*) revolving frame, (*d*) bearing, (*e*) worm rim, (*f*) coupling, (*g*) brake coil, (*h*) plunger, (*k*) crank lever, (*l*) thrust rod, (*m*) actuating levers, (*n*) compression spring.

employed in place of the D.C. brake coil for releasing the brake shoes.

The method of operating self-levelling machines will be described later, but at this juncture it will suffice to explain that such machines ensure accurate floor levelling irrespective of the load or stretch of ropes and independent of the lift attendant, and the auxiliary machine and its controller can, if necessary, be arranged to operate from a separate emergency power supply.

**With 3-phase Supply.**

With polyphase A.C. power supplies it is possible to employ the usual type of geared machine with a 2-speed motor having a speed range sometimes as high as 6 : 1 with a view to obtaining automatic floor levelling without the use of an auxiliary levelling machine. This type of self-levelling machine is more limited in its application than the machine shown in Fig. 42; moreover, the same degree of levelling accuracy cannot all things considered, be expected as from the auxiliary levelling drive, but it is quite satisfactory for many classes of service.

## CHAPTER IV

## ACCESSORY AND LIFT WELL EQUIPMENT

REFERENCE to Fig. 44 will show the disposition of the various operating devices, lift well, and machine-room equipment of a single-speed, car-switch operated, geared traction-machine installation. Similarly, the equipment for a variable-voltage, car-switch operated gearless traction-machine installation is shown in Fig. 45, in which it will be noticed that a secondary machine level is provided for the rope anchorages and governor; this secondary level avoids cramping the equipment in the machine-room and facilitates the cleaning and inspection of the secondary sheave and governor.

The main difference in the lift well equipment of these two installations are the stopping devices for the terminal floors and the buffers. For the single-speed lift, limit switches are employed for stopping, whereas for the variable-voltage lift a multiple-contact switch is fitted to the top of the car frame. For the single-speed lift, spring buffers are provided for the car and counterweight, but for the variable-voltage lift hydraulic buffers are employed. Whilst rope compensation is shown in Fig. 45 it is sometimes necessary to include it for geared-machine installation.

### Limit Switches for Drum-drive Lifts.

As explained in Chapter I., drum machines are now used only in exceptional instances, and it is now

usual practice to install traction machines. With a drum machine the ropes are anchored to the winding drum, and it follows that for any position the car may be in the lift well there is a corresponding position of the drum, and it is therefore possible to operate a set of limit switches by the movement

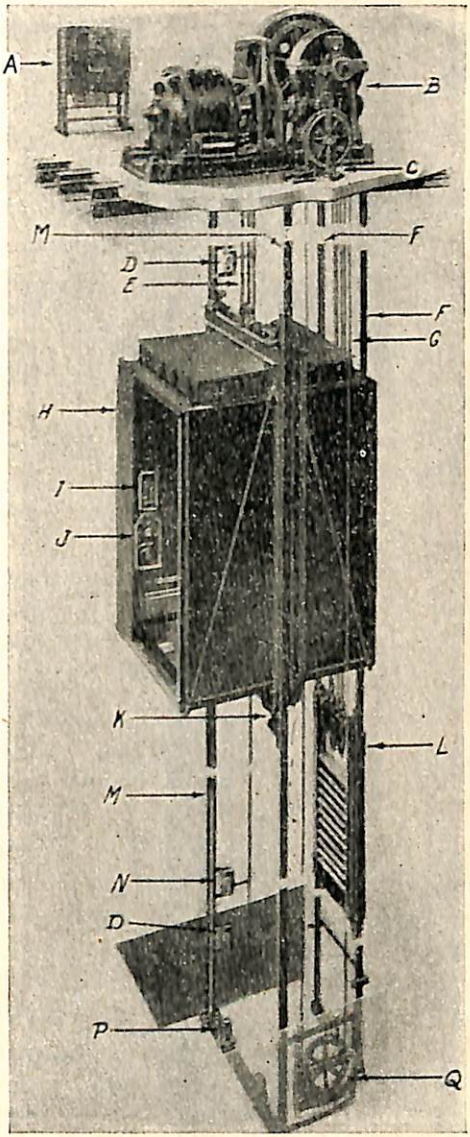
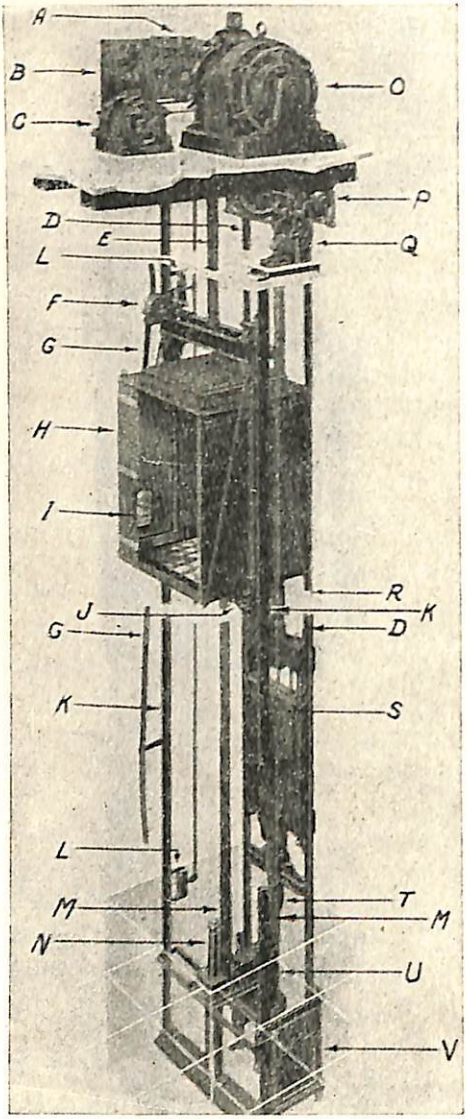



FIG. 44.—GEARED LIFT INSTALLATION.

*A*, Lift controller. B, Lift machine. *C*, Car governor. *D*, Overtravel limit switches. *E*, Lifting ropes. *F*, Counterweight guides. *G*, Governor rope. *H*, Car gate. *I*, Call indicator. *J*, Car switch. *K*, Car safety. *L*, Counterweight, *M*, Car guides. *N*, Stopping limit switch. *P*, Car buffer. *Q*, Governor rope tension frame.




of the drum for automatically stopping the car.

Such limit switches can be used for slowing or stopping the car at the terminal floors when car-switch operation is employed, or they can be arranged for automatic stopping at

FIG. 45.—GEARLESS LIFT INSTALLATION.

*A*, Lift controller. *B*, Motor - generator starter. *C*, Motor - generator. *D*, Counterweight guides. *E*, Lifting ropes. *F*, Stopping switch. *G*, Stopping switch cams. *H*, Car gate. *I*, Car switch. *J*, Car safety. *K*, Car guides. *L*, Overtravel limit switches. *M*, Compensating ropes. *N*, Car hydraulic buffer. *O*, Lift machine. *P*, Secondary sheave. *Q*, Car governor. *R*, Governor rope. *S*, Counterweight. *T*, Counterweight hydraulic buffer. *U*, Compensating rope tension frame. *V*, Governor rope tension frame.

any floor for push-button operation.

The limit switches used for car-switch operation with drum machines usually take the form of a screw-driven mechanism, and one type is shown in Fig. 46, where the sprocket (*a*) is driven from another sprocket on the drum shaft by a chain; as the sprocket (*a*) is keyed to the shaft (*b*) it causes the travelling nut (*c*) to travel along the screwed portion of the shaft, being prevented from rotating by the bow lever (*d*). When the car approaches the top landing the projection (*e*) on the travelling nut engages with a similar projection on the fixed nut (*f*), which causes the travelling nut (*c*) to move the

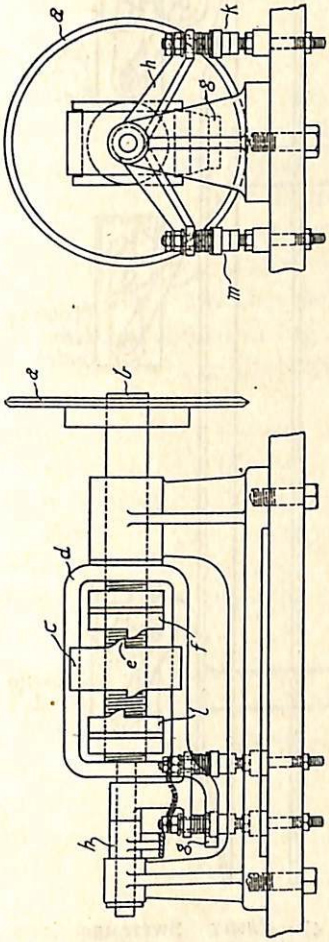



FIG. 46.—A LIMIT SWITCH USED FOR CAR-SWITCH OPERATION WITH DRUM MACHINES. This has a screw-driven mechanism.

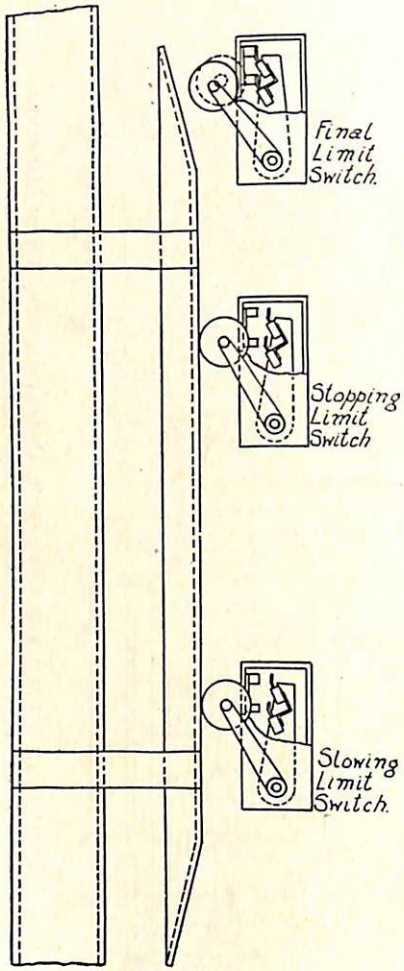



FIG. 47.—LIMIT SWITCHES FOR TRACTION-DRIVE LIFTS.

These are actuated by a cam attached to the car frame.

bow lever (*d*) with it until its tailpiece (*g*) engages with the "up" contact arm (*h*), and in raising it opens the "up" stopping contacts (*k*), so causing the controller switches to open and stop the car at the top floor. The operation for stopping a car at the lowest floor is similar except that the travelling nut (*c*) engages with the fixed nut (*l*) and opens the "down" contacts (*m*), the contact arms being held against their stationary contacts by a compression spring suitably housed. By so arranging the ratio of the machine and limit-switch sprockets and adjusting the distance between the fixed nuts (*f*) and (*l*), it is possible to use the same limit switch for any car rise.

Mechanically driven

limit switches for automatic push-button operation are usually mounted on the controller and will therefore be described later.

**Limit Switches for Traction-drive Lifts.**

With traction-drive machines it is not possible to employ the same arrangement of limit switches as with drum-drive because, as previously explained, the ropes creep round the sheave when it is rotating and the relative positions of the sheave and the car are therefore continually changing. To overcome this condition it is usual to install limit switches near the top and bottom of the lift well, as shown in Fig. 44, so arranged that they are actuated by a cam attached to the car frame, as shown in Fig. 47.

For single-speed lifts, two limit switches are usually fixed near the top and bottom of the lift well; when the stopping limit switch is opened by the cam on the car frame the car is stopped at the corresponding terminal floor; the other limit switch is an overtravel limit switch provided for emergency stopping should the car travel beyond its normal limits.

For slow-speed lifts the stopping limit switches can be mounted on the car frame, being actuated by cams fixed in the lift well in positions approaching the top and bottom floors.

With 2-speed operated lifts, however, it is necessary to provide two additional limit switches for slowing purposes. Reference to Fig. 47 will show the relative position of the limit switches for slowing, normal stopping, and overtravel stopping at the top of the lift well. The opening of a slowing limit switch, in conjunction with the slow-speed contactors on the

controller, causes the car to travel at slow speed until the normal stopping limit switch is opened.

Limit switches are an important component of the lift equipment and should therefore be designed to be opened positively and held open by the cam on the car frame. A limit switch intended for the reverse operation, that is, when the contacts are normally open and are closed by the cam on the car, should be so designed that the switch is opened by gravity and independently of any springs used in its construction, so that the failure of a spring will not create an undesirable condition.

**Stopping Switches.**

With multiple-speed lifts it is necessary to open several circuits in sequence to reduce the car speed before reaching a terminal floor, and this is accomplished by fitting a multiple-contact switch to the top of the car frame and arranging relatively long cams at the top and bottom of the well, as shown in Fig. 45, for actuating the switch. These multiple-contact switches have two sets of contacts, one set for the "up" direction and the other for the "down" direction.

**Overtravel Limit Switches.**

As their name implies, overtravel limit switches are provided at each end of the lift well, and are so situated that in the event of the car travelling a predetermined distance beyond a terminal floor the overtravel limit switch is opened. Such limit switches were at one time operated by means of an endless rope provided with stops which engaged with tappet plates mounted on the car, the switches opening the main circuit.

With the increased height of buildings coupled with the heavier duties of lifts this arrangement of main-line final limit switches became unsuitable, and it is now becoming usual practice to provide normal-type limit switches actuated by the cam on the car frame, the opening of the overtravel limit switch causing contactors on the controller to open and so cut off the power supply to the motor and apply the brake.

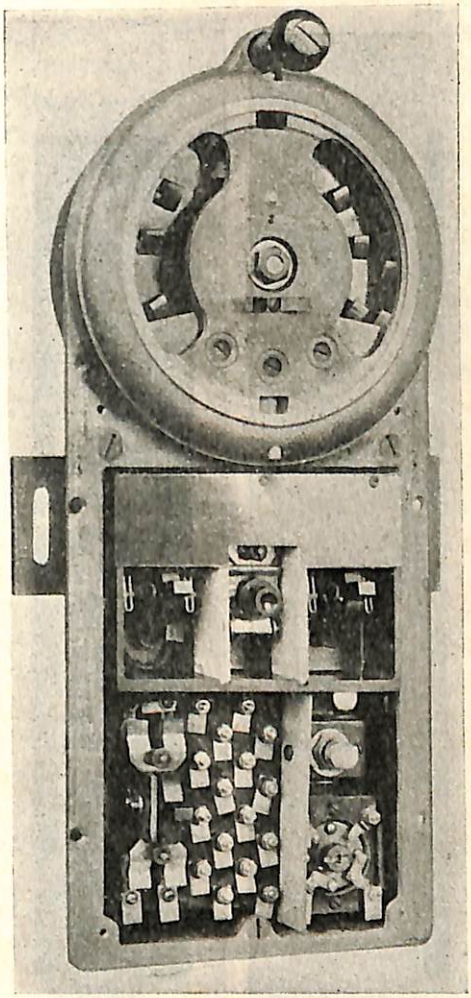


FIG. 48.—CAR SWITCH FOR ATTENDANT-OPERATED LIFT.

This has a contact segment with finger contacts in the circular portion and auxiliary switches are mounted below.

**Car Switches.**

With the

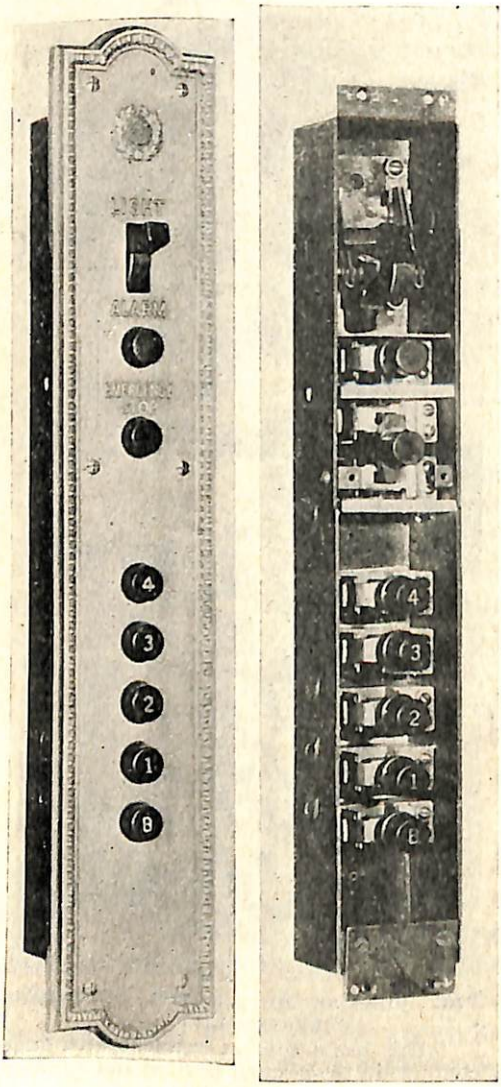



FIG. 49.—CAR PUSH-SWITCHES FOR AUTOMATICALLY OPERATED LIFT.

One making push is provided for each floor served and a breaking push for stopping in an emergency. Note also alarm and push car-light switch.

usual type of attendant-operated lifts the starting, stopping, reversing, and, with multiple-speed lifts, the slowing at intermediate floors is accomplished through the car switch mounted in the car. It may take the form of a tramway-type controller arranged with a vertical contact drum and contact fingers or of a common contact segment

which makes contact with finger contacts arranged as shown in Fig. 48. The latter arrangement is now very popular, as it lends itself to flush mounting. All types of car switches have spring-return handles so that the switch returns to the "off" position when the handle is released.

Most car switches now incorporate auxiliary switches for the car light, emergency stop, and for other purposes, depending upon the type of operation. With power-operated doors an additional contact is provided and so arranged that the operation of the doors is controlled by the car-switch handle.

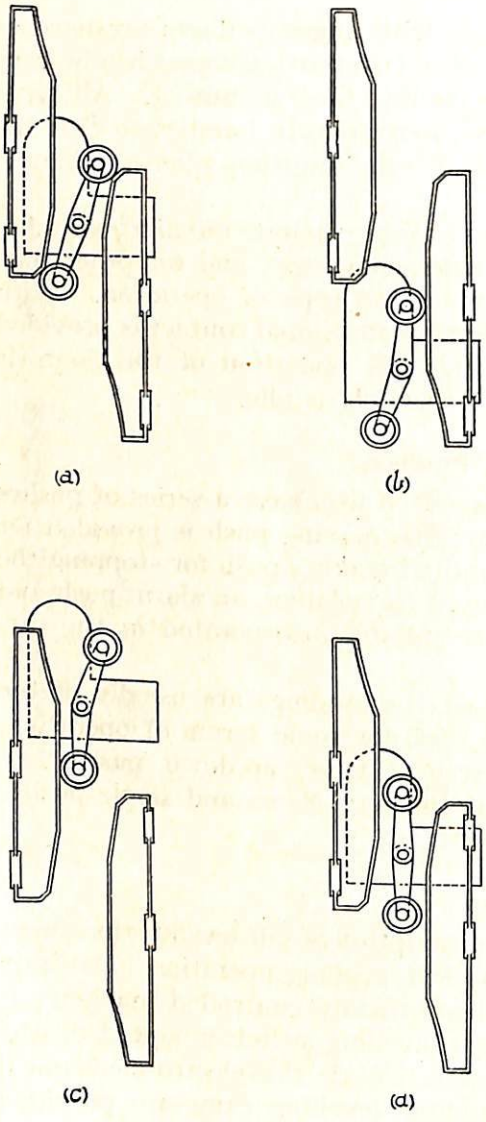
**Car and Landing Pushes.**

Automatically operated lifts have a series of pushes mounted in the car; one making push is provided for each floor served and a breaking push for stopping the car in an emergency. In addition, an alarm push and car-light switch are usually incorporated in the car-push control box.

The call pushes at the landings are usually of the single-button type, but for some forms of operation, which will be described later, up/down pushes are provided at the intermediate floors and single pushes at the terminal floors.

**Levelling Switches.**

As stated in the description of self-levelling machines in Chapter III, the self-levelling operation is entirely automatic. For rheostatically controlled machines it is usual to employ a levelling switch mounted on the top of the car frame. With the electro-mechanical type of levelling switch, levelling cams are provided




at each landing and so arranged that one of the two levers of the levelling switch will engage with a levelling cam if the car stops within about a foot above or below a landing.

This levelling switch is furnished with two sets of contacts and two roller levers, one set of contacts and their corresponding roller lever being provided for each direction

FIG. 50.
OPERATION OF ELECTRO-MECHANICAL TYPE OF LEVELLING SWITCH.

(*a*) Position of switch when car is level with floor.

(*b*) Car being raised to floor.

(*c*) Car being lowered.

(*e*) When car is passing floor.

of travel. When a lift serves more than two floors it is necessary to prevent the switch from functioning as the car passes a floor, and this is accomplished by arranging an electro-magnet for D.C., or a torque motor for A.C., to move the roller levers into a vertical position and so clear the levelling cams.

If the car stops just above a floor the roller levers are released and the "down" roller lever engages with the "down" levelling cam, causing the "down" contacts to close and complete the circuit for the "down" contactor on the levelling controller, which causes the levelling motor to bring the car to floor-level. When the car is at floor-level all the levelling-switch contacts are open. Reference to Fig. 51 will show the various positions of the levelling-switch roller levers with respect to the levelling cams; Fig. 50 (*a*) shows the rollers of the switch levers resting on the ends of the cams when the car is level with the floor; when the car is being raised to the floor the levers are in the position shown in Fig. 50 (*b*), and similarly Fig. 50 (*c*) shows the position when the car is being lowered. As previously mentioned, when the car is passing a floor the levers are held vertical, as illustrated in Fig. 50 (*d*).

For a high-speed lift or for an exceptionally heavy load it is advisable to have a 2-speed levelling motor, for which it is necessary to provide additional contacts in the levelling switch. These additional contacts are actuated by the usual roller levers, but the relative position of the roller levers and the normal face of the levelling cams is changed by providing another face to the cams, and as the roller arm moves from one face to the other the fast-speed levelling-switch contacts are opened, causing the car to travel at

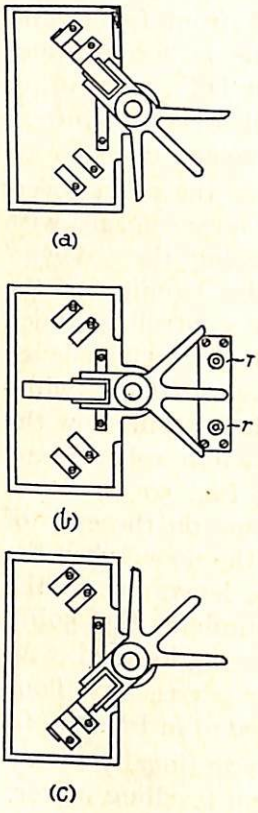



FIG. 51.—OPERATION OF AUTOMATIC INTERMEDIATE FLOOR LIMIT SWITCH.

(*a*) Position of switch above car. (*b*) Switch position at floor where car is standing. (*c*) Switch position below car.

slow speed before reaching floor-level.

Some types of levelling switches depend, in principle, upon the change in current produced by varying the reactance in coils carried on the car by magnetic plates mounted in the lift well at each floor, and others have a similar arrangement, but the magnetic plates change the reluctance of a magnetic circuit in order to actuate the levelling-switch contacts.

For high-speed lifts it is common practice to have a floor selector installed in the machine-room and driven by a drum or similar means, connected to the car by means of a steel rope or tape. Such floor selectors can not only be used for controlling the car-levelling operation, but also for automatic stopping, operating illuminated position indicators, direction indicators, cancelling answered calls on call indicators, and other similar operations. The advantage of such a device lies in the fact that it is situated in the machine-room, thus allowing easy access for cleaning and inspection.

**Intermediate-floor Switches.**

On slow-speed automatically operated lifts, limit switches are sometimes fitted at intermediate floors for automatically stopping the car. Such limit switches take different forms, but they all have three positions: that is, all the limit switches above the car have their levers in the "down" position, the "up" contacts being closed and the "down" contacts open, as shown in Fig. 51 (*a*). Similarly, all the limit switches below the car have their levers in the "up" position, the "down" contacts being closed and the "up" contacts open, as shown in Fig. 51 (*c*). The limit switch at the floor where the car is standing has its lever in the central position with both "up" and "down" contacts open, as shown in Fig. 51 (*b*).

The method of connecting these limit switches will be described with the aid of a wiring diagram in the section dealing with "Controllers." It will be appreciated that as a car passes an intermediate floor in, say, the "up" direction, the lever of the limit switch is moved from the "down" to the "up" position by a roller (*r*) on the car, and in doing it opens the "up" contacts and closes the "down" contacts in readiness for stopping the car at that floor when descending; the reverse sequence of operation takes place as a descending car passes a floor. When a car approaches a floor at which it is to stop, the lever is moved to the central position and the opening of its contacts causes the power supply to the motor to be interrupted and the brake applied.

**Landing-gate and Door Locks.**

The importance of reliable locking of landing gates

and doors cannot be overestimated. With all systems of locking it is necessary to make provision for both electrical and mechanical interlocking; the electrical interlock is required to prevent the car from being operated when a landing gate or door is open, and the mechanical interlock is necessary to prevent a gate or door from being opened unless the car is opposite that gate or door. As a further safety measure the gate or door can be mechanically locked before the lock contacts are closed.

For collapsible gates and single-hinged doors it is usual to employ a lock in which the electrical and mechanical interlocking are combined, and one form of this lock, together with its gate fitment, is shown in Fig. 52. It will be observed that with this type of lock it is possible to withdraw the gate fitment only when the lock roller (*a*) is depressed by the lock cam (*b*), which is mounted on the car frame, to move the lever (*c*) and allow the slide (*d*) to be raised by the finger (*e*) attached to the gate handle. When the beak (*f*) of the gate fitment is withdrawn from the lock the contacts situated at the top of the lock box are opened, thus preventing operation of the lift.

When single- or multiple-panel sliding doors are installed on car-switch operated lifts a most effective but simple form of electrical and mechanical interlock can be employed. Such locking devices usually incorporate a self-closing mechanism in which the door panel is operated by levers. When two sliding panels are employed the lengths of the levers are so arranged that the outer panel moves at twice the speed of the inner panel, and thus both panels complete their movement at the same time. Reference to

Fig. 53 will show the panel in the closed position with the operating levers in a horizontal position, thus preventing the doors from being opened from the landing side. The lock contact is operated by the levers, and is closed when the levers are horizontal. To ensure that the doors cannot be reopened from the landing as the contact is just closed, a pawl - and - rack device is fitted at the lower edge of the fast-speed panel. As the doors are opened a spring, suitably housed, is compressed, so that when the

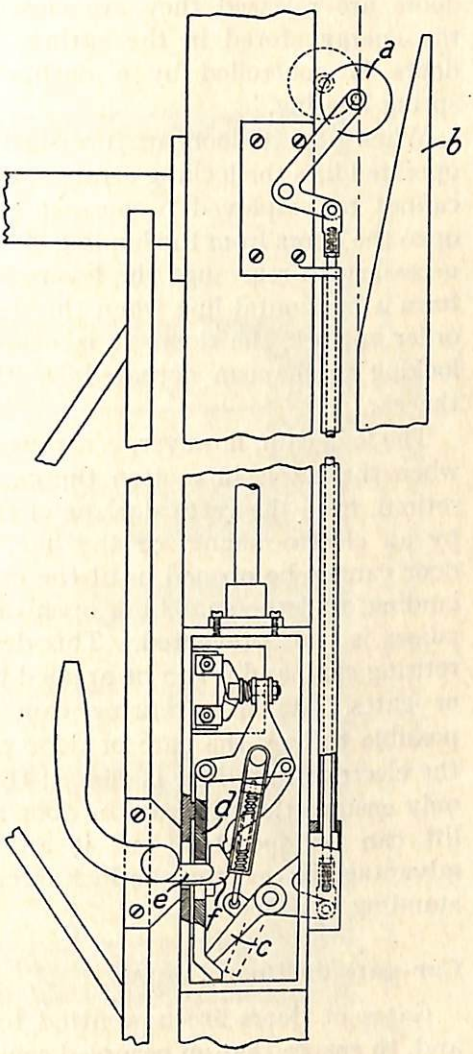



FIG. 52.—LOCK FOR COLLAPSIBLE GATES AND SINGLE-HINGED DOORS.

doors are released they are closed automatically by the energy stored in the spring; the closing of the doors is controlled by a dashpot attached to the spring housing.

When 2-speed doors are furnished with automatically operated lifts the locking arrangement as just described cannot be employed because it must be possible to open the doors from the landing side, and it is therefore necessary to rearrange the levers so that they do not form a horizontal line when the doors are closed. In order to lock the doors it is necessary to provide a locking mechanism actuated by the cam carried on the car.

The lock cam, however, is arranged to move; that is, when the car is in motion the cam is withdrawn, or retired, from the vertical plane of the lock roller levers by an electro-magnet or the like, so that a landing door cannot be opened until the car has stopped at a landing, and the snatching open of a door as the car passes is thus prevented. This device is known as a retiring cam, and it can be applied to all types of doors or gates. When a retiring cam is employed it is possible to lock the gate or door mechanically before the electrical interlock is closed; this arrangement not only ensures that the gate or door is locked before the lift can be operated, but it affords the additional advantage of opening the lock circuit when the car is standing at a floor.

### Car-gate or Door Contacts.

Gates or doors are now fitted to all car entrances, and, to ensure that an occupied car cannot be operated unless the car gate or door is closed, a contact, actuated

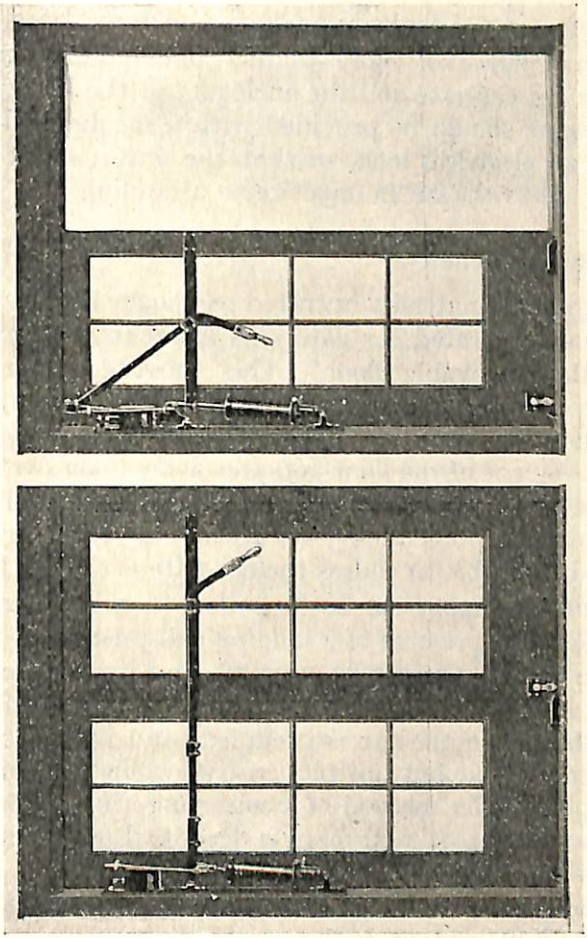


FIG. 53.—LOCKING DEVICE FOR SLIDING-PANEL DOORS ON CAR-SWITCH OPERATED LIFTS. Incorporating self-closing mechanism.

by the car gate or door, is provided which completes the operating circuit when closed. Such contacts should be so designed that they are positively opened by the opening of the gate or door.

When a space of more than a few inches exists between the car gate and the enclosure of the lift well, the car gate should be provided with a mechanical as well as an electrical lock, so that the gate cannot be opened unless the car is opposite to a landing.

**Car-floor Switches.**

With an automatically operated passenger lift having a manually operated car gate it is usual to provide a car with a movable floor. This movable floor is supported by compression springs and so arranged that when the car is occupied the floor is depressed. This movement of the floor actuates a car-floor switch, which in conjunction with a suitable relay mounted on the controller prevents an occupied car from being operated from the car unless the car gate is closed, but it permits an empty car to be called to a landing in response to the pressing of a landing call-push with the car gate open. The car-floor switch and its relay also prevent interference of the car operation by the landing call-pushes when the car is occupied, and in addition it renders the car buttons inoperative when the car is unoccupied. The method of connecting the car-floor switch and its associated relay is described later under "Controllers."

Cars of goods lifts are seldom equipped with movable floors, mainly because such service demands a solid platform construction and it is therefore necessary to close both the car and landing gate or door on

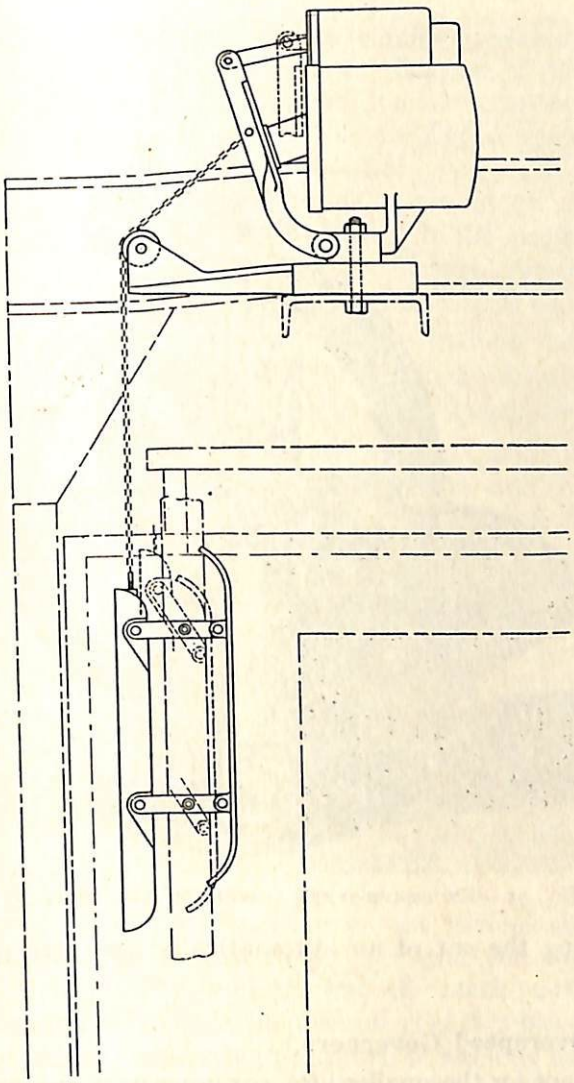


FIG. 54.—RETIRING CAM LOCKING ARRANGEMENT FOR LIFT GATE OR DOOR.

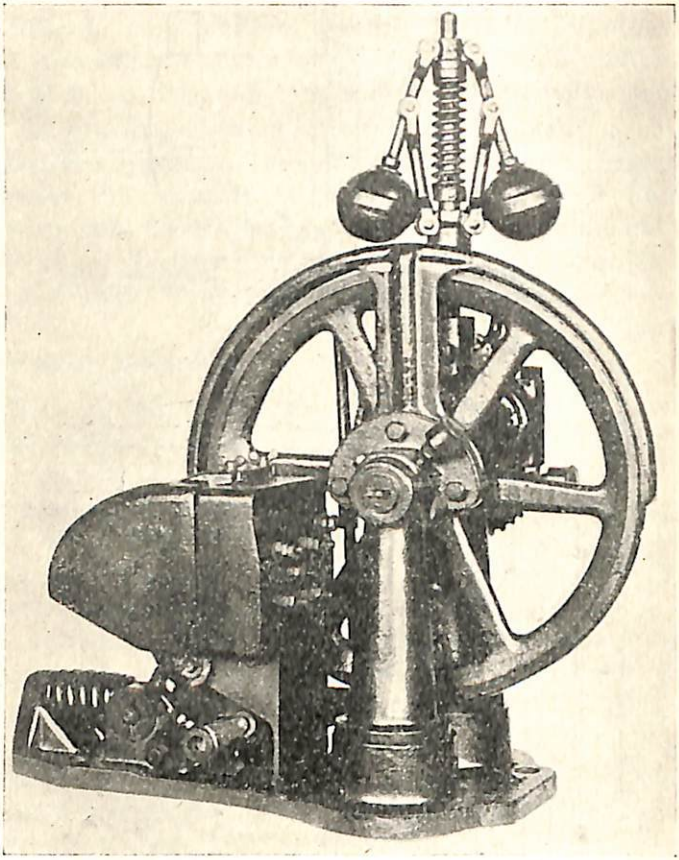


FIG. 55.—EXCESSIVE-SPEED GOVERNOR AND SWITCH.

vacating the car of an automatically operated goods lift.

**Car Overspeed Governors.**

Except for the smaller lifts, car governors are usually provided to bring the car safety mechanism into action

in the event of the car speed becoming excessive whilst descending. As explained in Chapter I, for car speeds of up to 200 ft. per min. the instantaneous type of car safety is employed, and for higher speeds the gradual type of safety is necessary.

With the instantaneous type of car safety a switch is usually incorporated in it so that in the event of the safety operating this switch is opened, causing the power supply to the motor and brake coil to be cut off. For the gradual type of car safety, where the car speed is higher, the governor can be equipped with a switch, which will open when a predetermined speed is reached. It is so arranged that should the car speed become excessive the governor switch is opened and, in turn, the power supply to the motor is interrupted and the brake applied; but should the car speed still increase with the car descending, the governor would call the car safety into action and so clamp the car to the guides.

Additional contacts can be fitted to the governor switches for obtaining the correct sequence of slowing with 2-speed A.C. car-switch operation should the lift attendant move the car-switch handle suddenly from the full-speed to the stop position.

**Flexible Cables.**

Electrical connection between the various switches and operating devices in the car and the electrical equipment at the landings and the machine-room is established by means of multiple-core flexible cables. These cables terminate in terminal boxes, one terminal box being mounted in a suitable position half-way up the lift wall, the other box being carried in the car

platform. Means for clamping the cables is usually arranged in the terminal box. By so arranging the length of the flexible cables that the loop formed by the cables just clears the floor of the pit no undue strain occurs in the cables when the car is at the top floor.

At this juncture it may be of interest to mention that the flexible cables of lifts installed in ships are guided to prevent them from fouling any lift well equipment as the ship rolls. The usual guiding device consists of a grooved pulley and guard, between which the flexible cables pass, and the pulley is mounted in a frame which travels between guides fixed to the side of the lift well. The weight of the pulley and its frame is such that the cables are held in the grooves of the pulleys as the car travels, and they are therefore prevented from swaying in the lift well.

## LIFT WELL EQUIPMENT.

### Car and Counterweight Guides.

It has already been mentioned that the guides for light-duty lifts are of round section and for other duties they are of T-section steel with machined working faces, the cross-section of the guides increasing with the load and size of the lift. As the guides must be capable of withstanding the load imposed upon them when the car or counterweight safety is applied, it will be realised that they must be securely fixed and have rigid joints. Car guides are used not only for guiding the car but also for supporting the limit switches, terminal boxes, levelling-switch cams, and the like, as shown in Figs. 44 and 45.

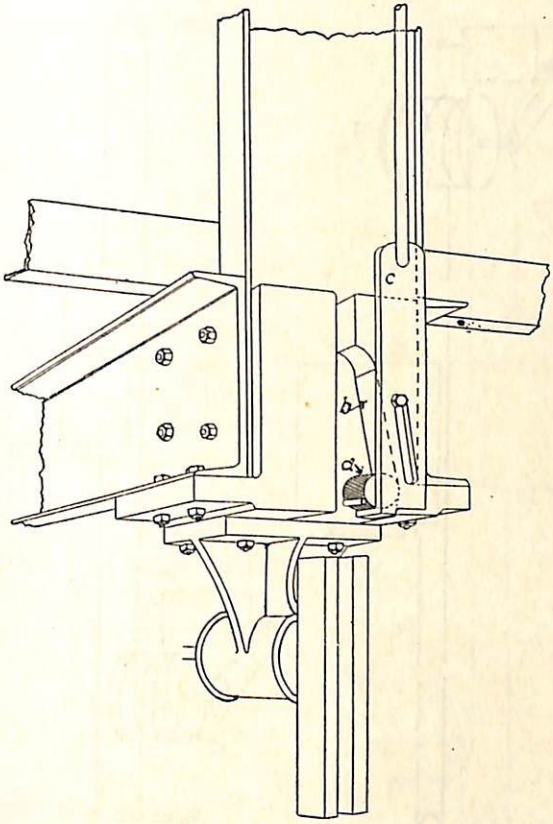



FIG. 56.—INSTANTANEOUS TYPE OF CAR SAFETY.

**Car Frames and Safeties.**

The car frame of a modern lift is continuous; that is, the top, side, and bottom members are made of steel sections rigidly connected, the car platform being fixed to the bottom members and steadied by suitable side braces attached to the top of the side members. With this arrangement the car bodywork is relieved from

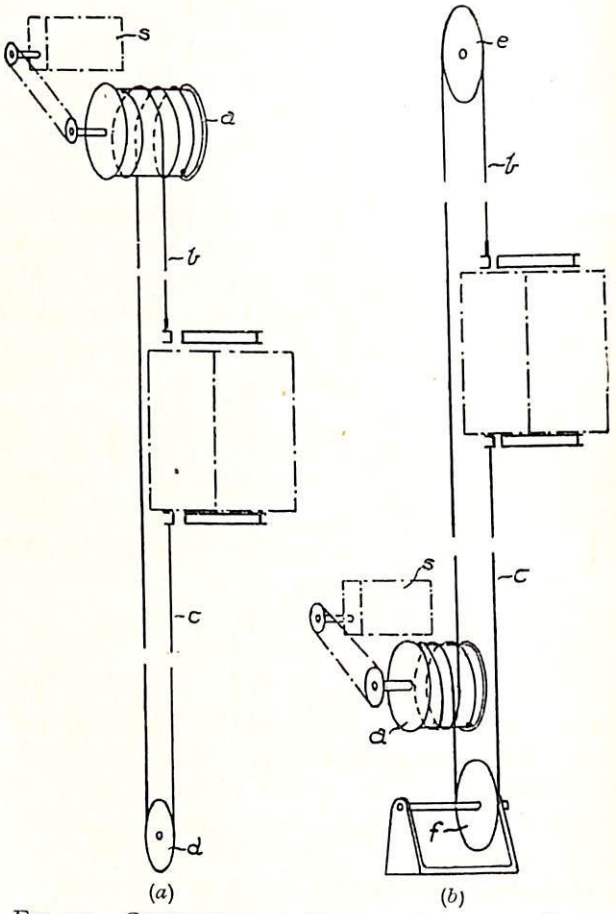



FIG. 57.—GROOVED-DRUM FORM OF AUXILIARY DRIVE.
(*a*) Machine-room above and (*b*) below.

stresses due to the raising and lowering of the car. Similarly, all devices such as levelling switches, stopping switches, retiring cams, lock cams, and door-

operating mechanism are carried from the car frame.

The instantaneous type of safety shown in Fig. 56 operates on the principle of a roller within an inclined plane. When the safety is called into service a roller on each side of the car safety is lifted up the inclined plane by a lifting rod until it engages with the car guides, and the descending car is thus held to both car guides by the wedging action of the rollers.

In other types of instantaneous safeties serrated cams suitably coupled and interconnected are employed. These cams are operated by a safety rope, which when pulled forces the cams against the guides, and owing to the progressive shape of the cams the weight of the car causes them to grip the guides and so hold the car.

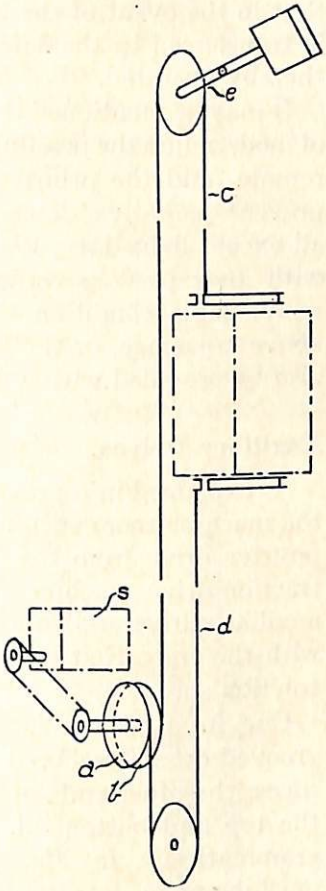



FIG. 58.—ANOTHER TYPE OF AUXILIARY-DRIVE MACHINE.

On small low-rise lifts the safety rope is not operated by a governor, but it passes up the lift well to two pulleys conveniently fixed to the machine-room floor or ceiling and then down to the counterweight, so

that in the event of the lifting ropes breaking the load is transferred to the safety rope and the car safety is thereby operated.

It may be mentioned that with the plurality of roping of modern lifts the possibility of rope failure is extremely remote, and the primary need for a car safety is to prevent excessive descending speed; for this reason all except light-duty, low-rise lifts should be equipped with overspeed governors. If, however, for some unavoidable condition the counterweight is situated above a passage, or the like, the counterweight should also be provided with a safety.

**Auxiliary Drives.**

As explained in a previous chapter, when a device in the machine-room such as a floor controller requires a positive drive from the car of a lift equipped with a traction-drive machine it is necessary to provide an auxiliary drive and so avoid the difficulties associated with the creep that occurs between the ropes and the traction sheave.

One form of auxiliary drive takes the form of a grooved drum, anchored to which are the ends of two ropes, the other ends of these ropes being attached to the top and bottom of the car frame as shown diagrammatically in Fig. 57 (*a*) and (*b*). When the machine-room is situated above the lift well the auxiliary drum (*a*) and its ropes (*b*) and (*c*) are arranged as shown in Fig. 57 (*a*) with an idler pulley (*d*) in the pit. For a machine-room "below" condition it is necessary to have a pulley (*e*) at the top of the lift well and a travelling pulley (*f*) in the pit, as shown in Fig. 57 (*b*); a travelling pulley is necessary in the pit

because as the rope is wound on or off the drum it travels along the drum. As one rope is unwound from the drum the other rope is wound on to it.

The drum is therefore provided with a single helical groove extending its whole length, the rope anchorages being made at the ends of the groove.

Another type of auxiliary-drive machine comprises two pulleys carried between two brackets, and each pulley has a flat-bottomed groove with flared sides and is sufficiently deep to accommodate a steel tape wound in it. These two pulleys (*a*) and (*b*), as will be observed in Fig. 58, take the place of the auxiliary drum previously described, and as one tape is unwound from one pulley the other tape is wound on to the other pulley. One tape (*c*) is connected between the top of the car frame and one pulley, and the other tape (*d*) between the bottom of the car frame and the other pulley.

Owing to the tape winding on to itself in the tape pulley the effective diameter of the pulley increases, and it is therefore necessary to make provision for the tape tension device (*e*), situated in the pit or at the top of the lift well, according to the position of the machine, to travel up and down as the tapes are wound on and off their pulleys.

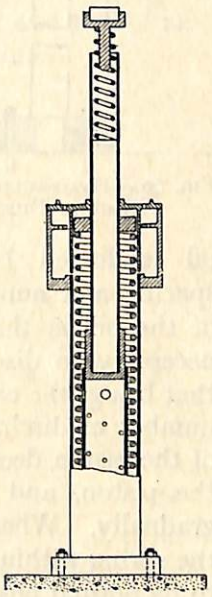


FIG. 59.—HYDRAULIC CAR BUFFER.

**Buffers.**

For slow- and medium-speed lifts

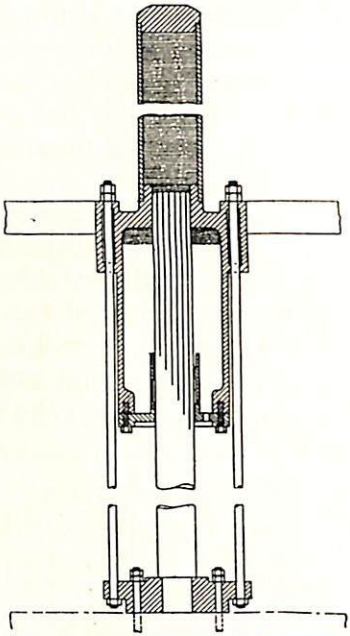


FIG. 60.—HYDRAULIC COUNTERWEIGHT BUFFER.

it is usual to include helical spring buffers in the pit to reduce the shock should the car or counterweight pass the normal limits of over travel.

With high-speed lifts, however, spring buffers would be of little use, and it is necessary to install hydraulic buffers, one type of which is shown in Fig. 59. This buffer is used for the car, and it has two cylinders filled with oil, the piston operating within the inner cylinder, which is provided with a number of holes through which the oil is forced by the action of the piston. The spacing and number of holes determine the pressure of the oil as the piston is depressed, and the force necessary to discharge the oil is the retarding force that brings the car to rest. As the piston descends the number of discharge holes is reduced, and the speed of the piston decreases until the last hole is passed by the piston, and the car is thereby brought to rest gradually. When the car is raised from the buffer, the spring within the buffer causes the piston to return to its normal position.

As a further safety feature a switch can be fitted to

the buffer, so that in the event of the buffer operating this switch is opened and the lift machine thereby brought to rest.

The hydraulic counterweight buffer is usually attached to the counterweight, and so arranged that the cylinder moves on guides attached to the counterweight frame. When the counterweight overtravels, the bottom of the buffer cylinder engages with the buffer block in the pit and the piston is forced into its cylinder as the counterweight continues its descent. In this type of buffer the piston is provided with a number of grooves of varying lengths extending from the bottom of the piston, so that as the piston is forced into the cylinder the effective area provided by the slots for the flow of oil becomes less, and the action is therefore similar to that of the car buffer.

## CHAPTER V

## SIGNALLING EQUIPMENT

THE efficiency of a lift installation depends to a large extent upon the provision of signals and indicators. Landing indicators show waiting passengers the direction in which a car is travelling and also its position in the lift well, and call indicators in the car with pushes at the landings are necessary with car-switch operated lifts to advise the attendant that the car is required at a certain floor. Signals and indicators take different forms to suit the particular methods of operation, and the usual systems will be described at some length.

### Call Indicators.

With the usual car-switch operated lift that serves up to five floors it is usual to furnish a single-type call indicator in the car with an audible warning. Such indicators have one flag-type movement for each floor served, and the older method of replacing the flags manually after the calls have been answered is being superseded by one of the electrical replacement methods. For lifts serving more than five floors it is an advantage to have "up-down" call indicators, in which two movements are provided for each intermediate floor and a single movement for each terminal floor, each movement being connected to the corresponding "up-down" call pushes at the intermediate

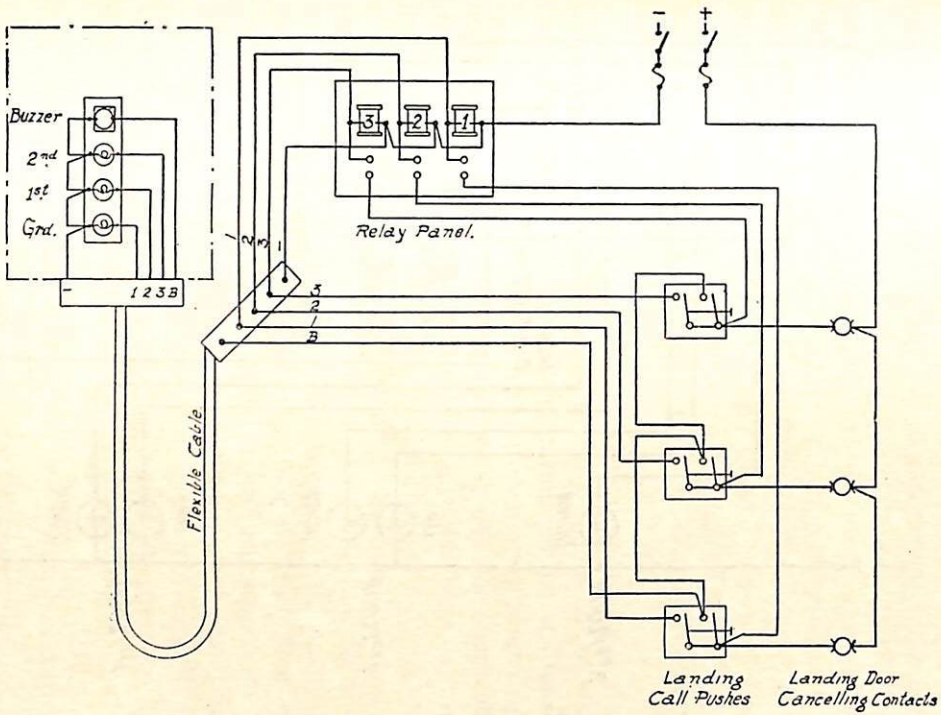



FIG. 61.—ILLUMINATED-TYPE CALL-INDICATOR DIAGRAM.

The indicators are arranged for automatic cancellation by the opening of a landing door in the above circuit.

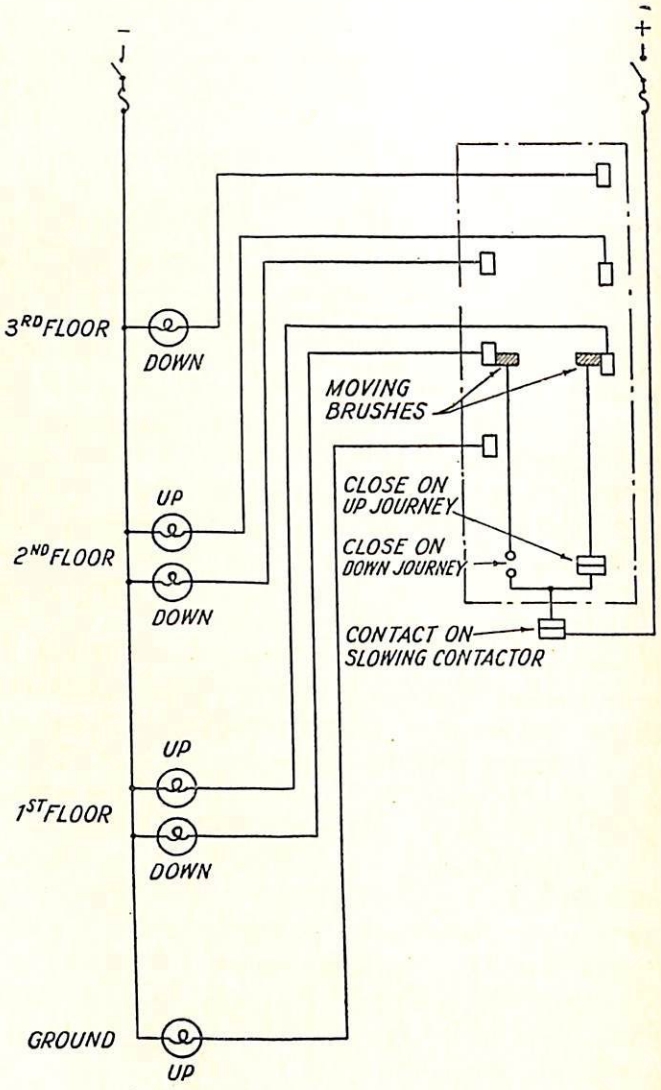



FIG. 62.—SYSTEM OF DIRECTIONAL ARRIVAL SIGNALS.

landings and single pushes at the terminal landings. The provision of "up-down" indicators enables the attendant, when ascending, to pass floors where "down" calls have been made and to answer them on the return journey; similarly, "up" calls are passed when descending. The "up" and "down" flag movements in the call indicator are replaced separately by the pressing of their own "up" or "down" replacement button.

An improvement on the flag-type call indicator is the illuminated type, in which lamps take the place of the flag movements. Such call indicators can be arranged for automatic cancellation by the opening of a landing door, as shown in Fig. 61, where it will be observed that the pressing of a landing button completes a circuit for its corresponding relay, which is held closely by its own contacts after the landing button has been released. It will be noticed that the buzzer in the car indicator is energised whenever a call push is operated, provided the landing door at that floor is closed. The illuminated signal in the car appears all the time its relay is closed, and as soon as the landing door is opened the contacts of the door-cancelling switch are open and the holding circuit of the relay is interrupted and the signal thereby cancelled.

**Intercommunicating Indicators for Battery of Lifts.**

When illuminated call indicators are provided for a battery of lifts it is an advantage to interconnect the indicators in all cars with the landing pushes so that the pressing of a landing button causes a signal to appear in each car; then the lift attendant travelling in the required direction nearest the floor where the

call was originated can answer that call. The signals with such a system are cancelled automatically by the stopping of a car at a floor. With intercommunicating indicators, "up-down" car indicators are employed and "up-down" arrival signals are fitted above the lift entrances at the intermediate floors with single signals at the terminal entrances. These landing signals indicate to the waiting passengers which car of the battery of lifts is stopping at a floor and also its direction of travel.

One system of directional arrival signals together with its switchgear is shown in Fig. 62, in which the

FIG. 63.—ELECTRICAL TYPE POSITION INDICATOR.

switchgear is incorporated in a selector. Reference to the diagram will show that as soon as a car slows down to stop at a floor, the slow-speed contactor on the controller drops out and closes a pair of contacts which complete the circuit for the signal lamp at the floor where it will stop; if a car passes a floor, the slow-speed contactor will not function and consequently no signal will appear. Each of the moving contacts on the selector is connected to a contact so arranged that when one contact is closed the other is open, and directional signalling is thus accomplished. These directional contacts can be mounted on the selector and friction operated, or alternatively may be arranged on suitable controller contactors.

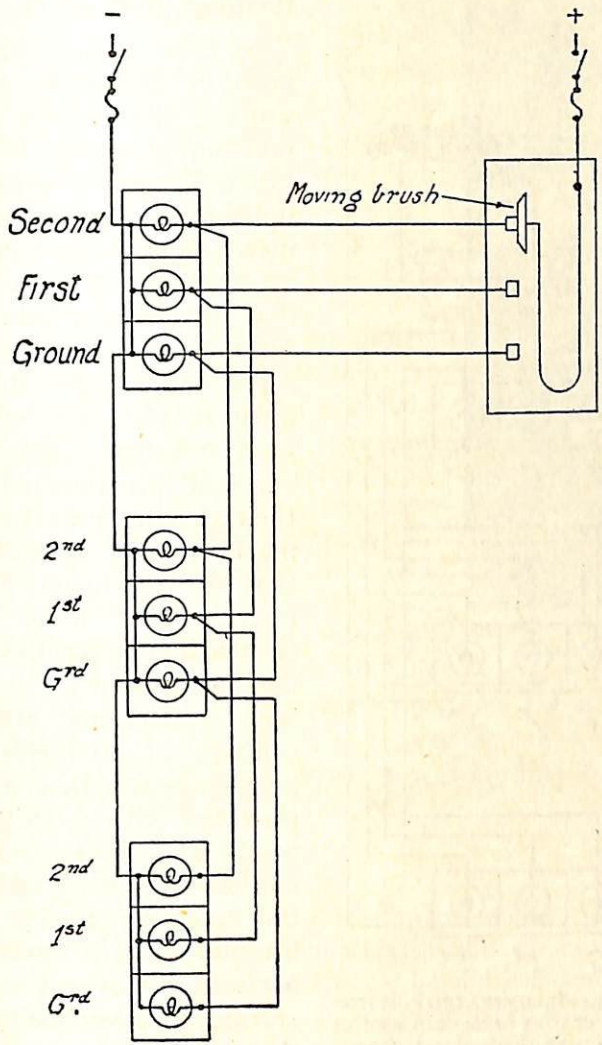



FIG. 64.—ILLUMINATED POSITION INDICATOR FOR LIFT PROVIDED WITH FLOOR SELECTOR.

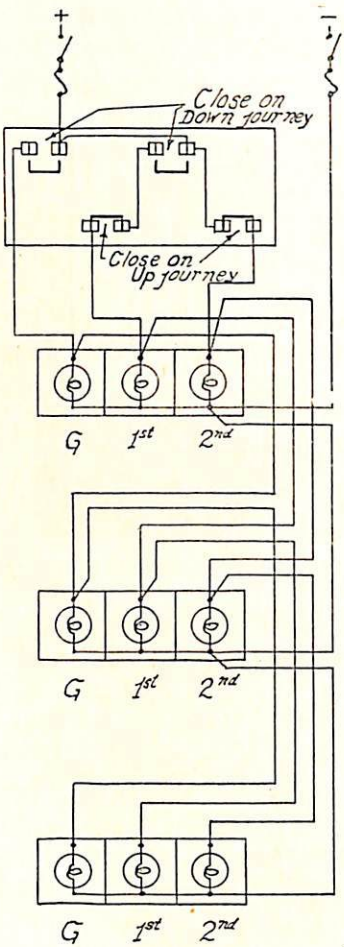



FIG. 65.—ILLUMINATED POSITION INDICATORS OPERATED BY SET OF LIMIT SWITCHES GEAR.

**Position Indicators.**

As their name implies, position indicators show waiting passengers the position of a car in the lift well. Some position indicators are entirely mechanical, consisting of a pointer moving round a dial, or they may take the form of a model lift car reproducing the movement of the car; but as such indicators are mechanically connected to their driving unit in the machine-room it follows that site conditions often restrict their use. The electrical-type position indicator, however, has no such restrictions, and it consists of a series of lamps mounted in a casing provided with a suitable front and glass screen marked to correspond to the floors served by the lift, and it can be mounted horizontally over the lift entrances or vertically at the side of them.

When illuminated

position indicators are installed for a lift provided with a floor selector the arrangement of selector contacts and wiring is shown in Fig. 64. If however, the method of operation is such that a floor selector is not required, it is usual to provide a set of limit switchgear to operate the position indicators, as shown in Fig. 65. With the limit switchgear two sets of limit switches are provided. One set closes as the car ascends and opens as it descends, and similarly the other set closes as the car descends and opens as it ascends, so that the signals for an intermediate floor appear as the car approaches it and are extinguished as it leaves the floor for either direction of travel. Direction signals are sometimes included in the position indicators and consist of lamps connected to contacts on the reversing switch of the controller, so that while the car is in motion one set of direction signals, according to the direction of travel, is illuminated.

FIG. 66.—"IN USE" SIGNAL.

**"Car Coming" Signals.**

When the usual type of push-button operated lift is installed in an enclosed lift well with solid doors it is a convenience to know when the car has been dispatched to a floor or has responded to the pressing of a landing call push, and this can be accomplished by incorporating in the call push a lamp arranged behind a trans-

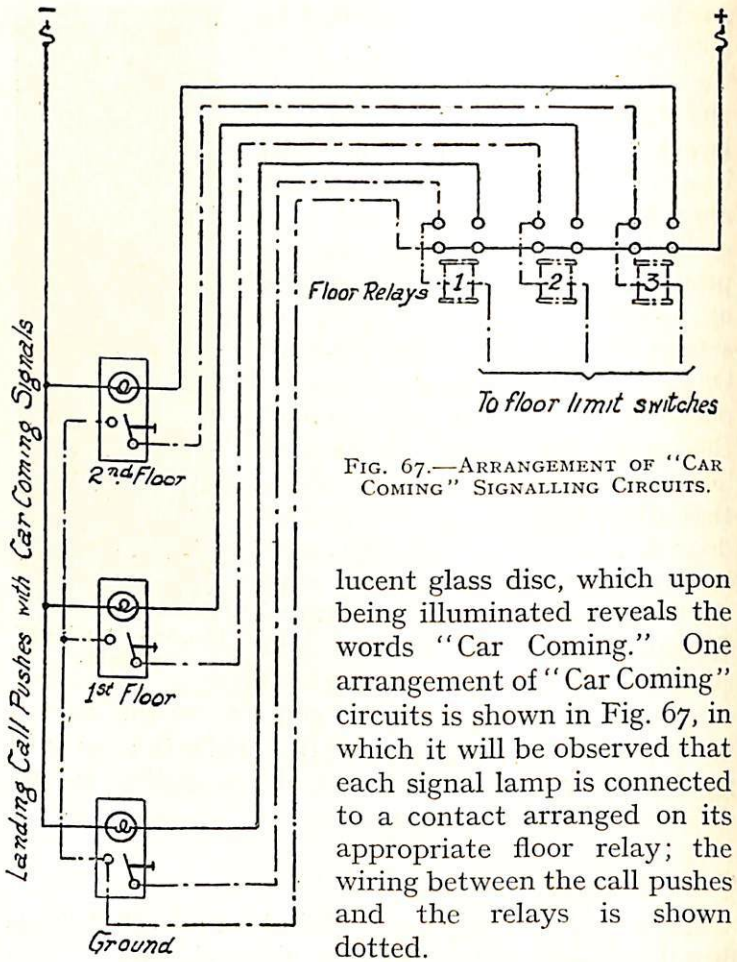



FIG. 67.—ARRANGEMENT OF "CAR COMING" SIGNALLING CIRCUITS.

lucent glass disc, which upon being illuminated reveals the words "Car Coming." One arrangement of "Car Coming" circuits is shown in Fig. 67, in which it will be observed that each signal lamp is connected to a contact arranged on its appropriate floor relay; the wiring between the call pushes and the relays is shown dotted.

**"In Use" Signals.**

As an alternative to "Car Coming" signals it is possible to provide "In Use" signals, in which the

signal lamps in the landing call pushes are connected in parallel and are illuminated while the car is in motion. With this arrangement the glass discs in the landing call pushes are marked with the words "In Use."

## CHAPTER VI

# CONTROLLERS

## SYSTEMS OF OPERATION

BEFORE explaining the construction and functions of the many different types of lift controllers it would be advantageous to give a brief description of the various systems of operation that are in use.

### Hand-rope Operation.

Hand-rope operation was the first method used for electric lifts, but owing to its being limited to slow car speeds, coupled with the difficulties associated with the interlocking of the controller operation with the landing-door or gate locks, it is now considered obsolete. Whilst many hand-rope operated lifts have been changed to other types of operation, some are still in service.

The reversing switch and main switch of hand-rope controllers are actuated by cams mounted on a shaft connected to a rope drum. To this drum is wound on and attached the hand rope, which passes through the car to a tension frame in the pit and then up the lift well, and is again attached to the rope drum, so that a downward pull of the rope rotates the drum in one direction and closes the "up" reversing switch to start the car in the "up" direction; an upward pull of the hand-rope causes the car to start in the other direction. By moving the rope in the same direction as the car is

travelling the car is stopped, and it is therefore possible to stop the car automatically at the terminal floors by connecting two stops to the hand rope and allowing suitable stop plates fixed to the car to engage with the stops on the hand rope.

**Car-switch Operation.**

With car-switch operation a lift attendant is necessary, and the car switch is furnished with a self-centring handle which when moved from the central position in one direction causes its contacts to close and complete the circuits for the various controller contactors and so start the car in the "up" direction, and when the handle is moved in the opposite direction the car descends, provided the car and landing gates or doors are closed. When multiple-speed lifts are employed the movement of the car-switch handle closes additional contacts to complete the circuit for the fast-speed contactors on the controller.

The operation from the car switch is made subject to the limit switches in the lift well, so that at terminal floors the car is stopped automatically and, when multiple-speed operation is provided, the car is slowed down by additional limit switches independently of the car switch.

**Semi-automatic Operation.**

Semi-automatic operation, or "Up-Down-Stop" operation as it is sometimes known, is now usually restricted to service lifts serving two floors. At each landing is fitted a push box containing three pushes, one for "up," one for "down," and the other for stopping the car. The momentary pressing of an "up" or "down," button at either landing will call or

dispatch the car, and on arriving at the floor it will automatically stop. This operation does not require the floor relays or floor-limit switches as used with automatic forms of push-button operation. Semi-automatic operation has in the past been used for slow-speed lifts serving more than two floors, but collapsible gates or the like must be provided at each landing to enable a person at a landing to ascertain whether the car is above or below that floor in order that the appropriate button is pressed to call the lift. Moreover, as no provision for automatic stopping at intermediate floors is made with this type of operation, it is necessary to press the car or landing stop push to stop the car when it approaches the required floor.

**Single Push-button Operation.**

The usual system of push-button operation requires a set of dispatch pushes, one for each floor served, and a stop push in the car with a single call push at each landing. The pressing of a landing call button causes the car, if not in use, to proceed to that floor and stop. Similarly, after a passenger has entered the car and closed the car gate and landing door and pressed a car button, the car is dispatched to the designated floor. After the car is vacated and the landing door closed the car is available for the next call.

As already explained, with goods lifts it is necessary to close both car gates and landing doors after leaving the car.

It may be of interest to mention that the above method of operation is now known as single push-button operation to distinguish it from other forms of push-button operation.

**Dual Operation.**

In some buildings the lift service is such that a lift attendant is required only for certain times of the day, and to meet this condition dual operation can be employed. Dual operation can be applied to many types or combinations of operation, but the usual form is by means of car switch and push-button.

The operation during busy times is by means of the car switch, and the landing pushes are then connected to a call indicator in the car; for other times, when the services of an attendant are not warranted, the operation is changed to automatic push-button, the car buttons being used to dispatch the car and the landing buttons then serving to call the lift. The change-over from car-switch operation to push-button operation is effected by means of a change-over switch, which may be operated either manually or by remote control.

Another form of dual operation is available in which the car buttons are used for both attendant and non-attendant operations, the change-over switch being employed to change the landing call push connections from the call indicator to the lift controller.

The former method of dual operation is usually employed when a higher car speed is required with car-switch operation than push-button operation, but with the latter method the car travels at the same speed with or without the attendant.

**Collective Operation.**

With the usual single push-button operated lifts the car is in use from the time it responds to the pressing of a landing button until it is vacated by the person or

persons using it; any calls that may be made at other landings whilst the lift is in use have no effect, and it is therefore possible for a car to pass a floor at which intending passengers are waiting. It is also possible for a car to travel to, say, the ground floor, and after the transfer of passengers to proceed to an upper floor whilst a person is waiting at the basement. Such conditions would prevail in busy buildings of many stories, but they have been overcome by a system known as collective operation.

As its name implies, collective operation ensures that the car will stop at all floors for which either car or landing button have been pressed, the various calls being registered or collected whether the car is in motion or not, and these calls are answered in floor sequence for each direction of travel. To avoid, say, an ascending car stopping at a landing where a waiting passenger wishes to descend, "up-down" landing pushes are provided at the intermediate floors, so that the call made by the pressing of, say, a "down" landing button whilst the car is ascending remains registered until the car returns. With this system of operation there is no need for the car to proceed to a terminal floor before reversing; as soon as the car has answered the highest or lowest call registered it is free to reverse to answer the next call. A lift with collective operation functions the same as the usual single automatic push-button lift when one car or one landing button is pressed, but becomes collective when a button is pressed while a call is registered.

This system of operation may be applied to two adjacent lifts employing one common set of landing buttons; with this arrangement the car nearest the

landing where a call is made and travelling in the required direction will answer the call.

FIG. 68.—"UP-DOWN" SIGNAL.

**Signal Operation.**

It was explained earlier that to obtain the maximum service from a given number of lifts it is necessary to relieve the attendant of as many of his duties as practicable and to employ automatic operation wherever possible. These requirements have been satisfied with signal operation.

With this system of operation a battery of high-speed lifts having gearless machines and variable-voltage control with power-operated car and landing doors should be installed. At the intermediate landings "up-down" signals and "up-down" pushes are provided, with single signals and single pushes at the terminal floors. In each car is fitted an operating panel, which comprises a set of pushes corresponding to the floors served, a starting lever which is used to start the lift as well as control the car and landing doors, and the usual auxiliary switches for the car light, emergency stopping, starting and stopping the motor-generator set, and the like.

The pressing of a landing button is registered on a relay panel and causes the first car travelling in the desired direction to stop automatically at that floor. Persons entering the car announce their destinations in the usual manner and the attendant registers these floors by pressing the corresponding car buttons. Upon

FIG. 69. — "UP-DOWN" PUSHES.

moving the starting lever the car and landing doors close and the car proceeds to the first floor for which a button was pressed, where it stops, and the car and landing doors open automatically. After the transfer of passengers the starting lever is again moved and the sequence of operation repeated. Although the stopping of a car with signal operation is automatic and independent of the attendant, he can if necessary operate a switch to prevent the car from stopping at any intermediate floor, and any registered landing call for that floor is then answered by the next car travelling in the same direction.

The approach and direction of a car stopping at a floor is signalled by the illumination of the direction-arrival indicator at that floor, and by this means the waiting passengers are advised which car in the battery of lifts is stopping; the signal is cancelled as the car leaves the floor. It will be appreciated that as the car answers calls in floor sequence for both directions of travel, the order in which the car or landing buttons are pressed is immaterial, and the stopping of one car in response to a call prevents other cars from stopping for the same call.

The important advantage of signal operation lies in the fact that it is independent of the skill or memory of the lift attendant; the relatively high passenger-carrying capacity of a battery of lifts having this form

of operation is due to the combination of the automatic opening of the car or landing doors when the car arrives at a floor, the elimination of false stops, the advanced signalling of the car which will answer a landing call, and the automatic stopping of the cars to take waiting passengers.

## LIFT CONTROLLERS

With all electric lifts it is necessary to furnish a controller by which the starting, stopping, direction of rotation, and speed of the lift motor is controlled. For some systems of operation auxiliary controllers are required in addition to the main controller for controlling auxiliary motors used for levelling purposes, and with automatic lifts it is necessary to provide floor controllers for stopping the car automatically. With variable-voltage control a separate set of switchgear, known as a starter, is needed for the automatic starting and stopping of the motor-generator set.

### Control Panels.

Lift controllers usually consist of a panel of slate, or other insulating material, upon which the various main contactors and relays for controlling the lift are mounted. This panel is carried on a suitable steel frame or in a steel casing, the resistors for the main and auxiliary circuits being attached to the controller frame. Hand-rope operated controllers were provided with cast-iron cases to house the switch cams and switches, the latter being mounted on slate panels.

### Types of Controllers.

The two important functions common to all lift controllers are the reversing and starting of the lift

motor, but the methods by which these operations are accomplished must of necessity vary with the nature of the power supply and the method of control, i.e. rheostatic or variable-voltage. Moreover, the design and construction of contactors for A.C. must differ from those used for D.C., and a further development in lift practice is the use of D.C. switches for controlling A.C. motors, the D.C. power supply for the operating circuit being obtained from metal-plate rectifiers or small motor-generator sets. These different types of controllers will therefore be divided, for the purpose of description, into three classes, namely, D.C. rheostatic, A.C. rheostatic, and variable-voltage.

## DIRECT CURRENT CONTROLLERS

Apart from the hand-rope controller, in which the switches for starting, stopping, and reversing are actuated mechanically, controller switches are operated electro-magnetically. The vertical solenoid type of reversing switch and rheostat is being superseded by the modern contactor, which is more compact and generally superior.

### Contactor for Main Circuits.

One type of contactor used for main circuits is shown in Fig. 70, in which it will be observed that the magnet frame (*a*) is bolted to the controller panel (*b*), and the switch arm (*c*) moves about its fulcrum (*d*). Fixed to the magnet frame (*a*) is the operating coil (*e*), within which are the stationary magnet core (*f*) and the moving magnet core (*g*); the stationary core (*f*) is riveted to the magnet frame (*a*), and the moving core is riveted to the switch arm (*c*). The moving

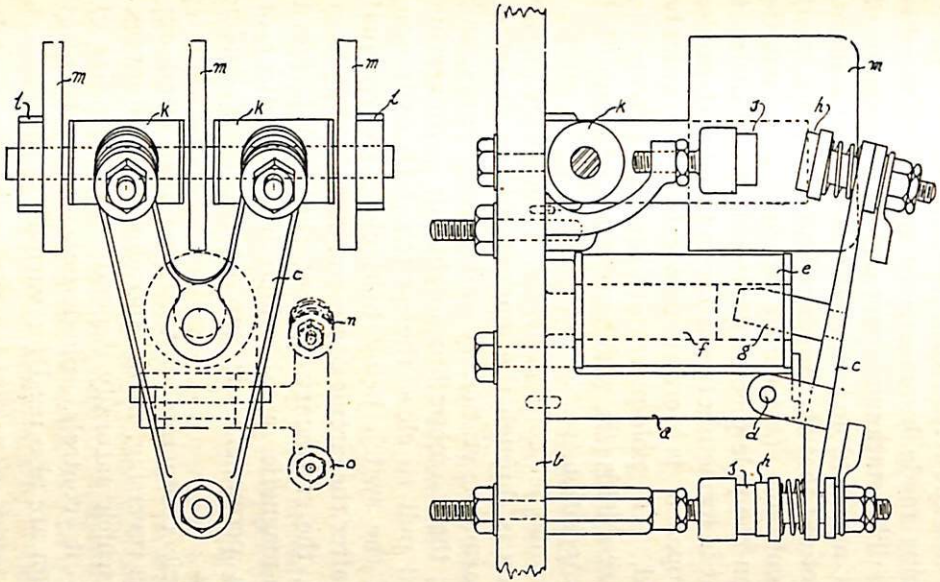



FIG. 70.—DOUBLE-POLE CONTACTOR USED FOR MAIN CIRCUITS.

(*a*) Magnet frame; (*b*) panel; (*c*) switch arm; (*d*) fulcrum; (*e*) operating coil; (*f*) stationary magnet core; (*g*) moving magnet core; (*h*) moving contacts; (*j*) stationary contacts; (*k*) blow-out coils; (*l*) pole-pieces; (*m*) arc shields; (*n*) and (*o*) auxiliary making and breaking contacts.

contacts (*h*) are made of copper, and are insulated from the switch arm by suitable insulators and are spring loaded, the electrical connections to these contacts being made by means of insulated flexible connectors. The stationary contacts (*j*) are made of carbon and are held in adjustable contact holders. It will be noticed that the upper contacts are provided with blow-out coils (*k*), which produce a magnetic field between the pole pieces (*l*) of such direction that any arc that is formed between the contacts when the switch is opened is forced upwards and quickly extinguished. The pole-pieces are protected from the arc by the arc shields (*m*), which are made of a moulded asbestos composition.

When the magnet coil is energised, the path of the magnetic flux is through the magnet frame, a part of the switch arm, the stationary and moving cores, and the air gap; the magnetic flux in this air gap exerting the required pull to close the switch. To overcome the risk of the switch being held close by residual magnetism after the circuit of the magnet coil has been interrupted, the stationary magnet core (*f*) is faced with a non-magnetic metal, which has the effect of providing a permanent air gap as described under D.C. brakes.

Double-pole contactors of the type just cited are employed as reversing, main, and slowing contactors, the size of which naturally depends upon the size of the motor it controls. Single-pole contactors of similar design are also used for various purposes.

**Auxiliary Contacts.**

By attaching an auxiliary arm to the switch arm

it is possible to equip the contactor with auxiliary making and/or breaking contacts, for use in the various operating circuits, as indicated by the chain line in front elevation of Fig. 70; contact (*n*) is normally open and contact (*o*) is normally closed. To prevent the possibility of both reversing contactors being closed simultaneously and causing a short-circuit, it is usual to provide a mechanical interlock, one form of which comprises a lever pivoted between the contactors, and it has the effect of holding one contactor open when the other one is closed.

**Relays for controlling Operating Circuits.**

With most lift controllers it is necessary to provide various relays for controlling the operating circuits. Such relays employ the same principle as the larger contactors, but owing to the smaller currents they handle they are correspondingly smaller and do not require blow-out coils.

**Purpose of Starting Resistance.**

Owing to the comparatively low resistance of the armature circuit of a D.C. motor, it is necessary to insert a resistance in series with the armature when starting and thereby limit the starting current to a value which, in conjunction with the strength of the magnetic field due to the field windings, will produce sufficient torque to start the lift. As soon as the armature rotates, a counter-e.m.f. is generated and, as the value of this counter-e.m.f. is a function of the armature speed, the initial starting current falls as the motor accelerates. It is therefore necessary to reduce the value of the starting resistance in a series of steps, and as each

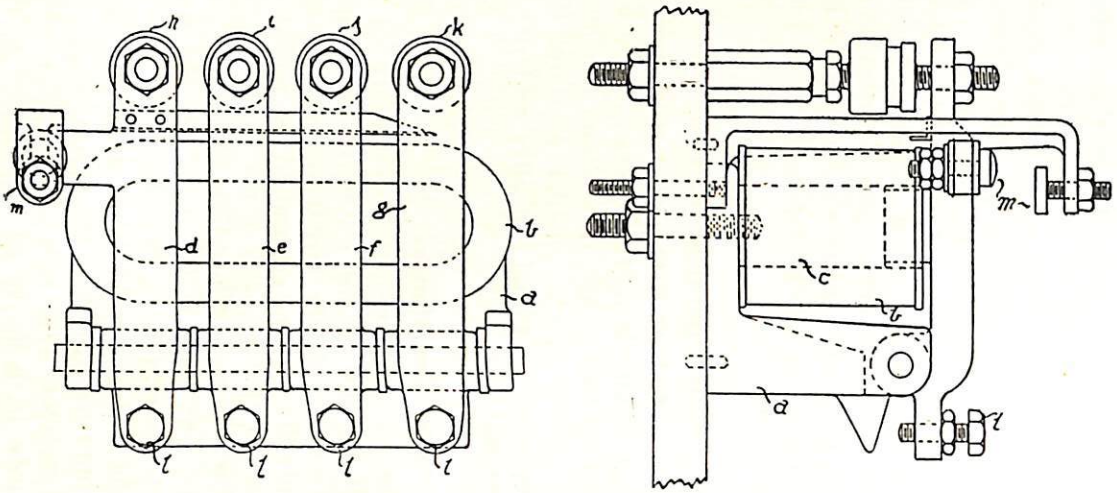



FIG. 71.—ACCELERATING SWITCH FOR AUTOMATICALLY CUTTING OUT STARTING RESISTANCE OF D.C. MOTOR.

The switch is controlled by the counter-e.m.f. (*a*) Magnet frame; (*b*) magnet coil; (*c*) magnet core; (*d*), (*e*), (*f*), and (*g*) four switch arms; (*h*), (*i*), (*j*), and (*k*) contacts; (*l*) adjusting screws for adjusting lengths of air gaps between magnet core and switch arms (these are regulated so as to increase progressively); (*m*) auxiliary contacts.

step of resistance is cut out the armature speed is increased until the series field winding is finally cut out and the motor runs at full speed; in order that the armature will have sufficient time to accelerate, a time-lag must be allowed between the cutting out of each step of resistance.

**Use of Accelerating Switch.**

Various devices such as dashpots, eddy-current brakes, inductances, and the like are employed on lift controllers to retard the cutting out of the starting resistance. Another method, however, takes advantage of the fact that the counter-e.m.f. increases with the speed, and an accelerating switch that is controlled by the counter-e.m.f. is shown in Fig. 71. Reference to Fig. 71 will show that this particular switch consists of a magnet frame (*a*) which carries the magnet coil (*b*) on its magnet core (*c*), and hinged at the bottom of the frame are four switch arms (*d*), (*e*), (*f*), and (*g*). Each switch arm is provided with a contact which closes on to its corresponding contact (*h*), (*i*), (*j*), or (*k*) fixed to the controller panel. By means of the adjusting screws (*l*) the lengths of the air gaps between the magnet core and the switch arms can be so regulated that they increase progressively, that of the switch arm (*d*) being the minimum. The purpose of the auxiliary contacts (*m*) will be explained later.

**How Accelerating Switch Operates.**

On starting the lift, a reversing contactor closes and power is supplied to the armature through the starting resistance. As the armature accelerates, the counter-e.m.f. increases, and as the magnet coil

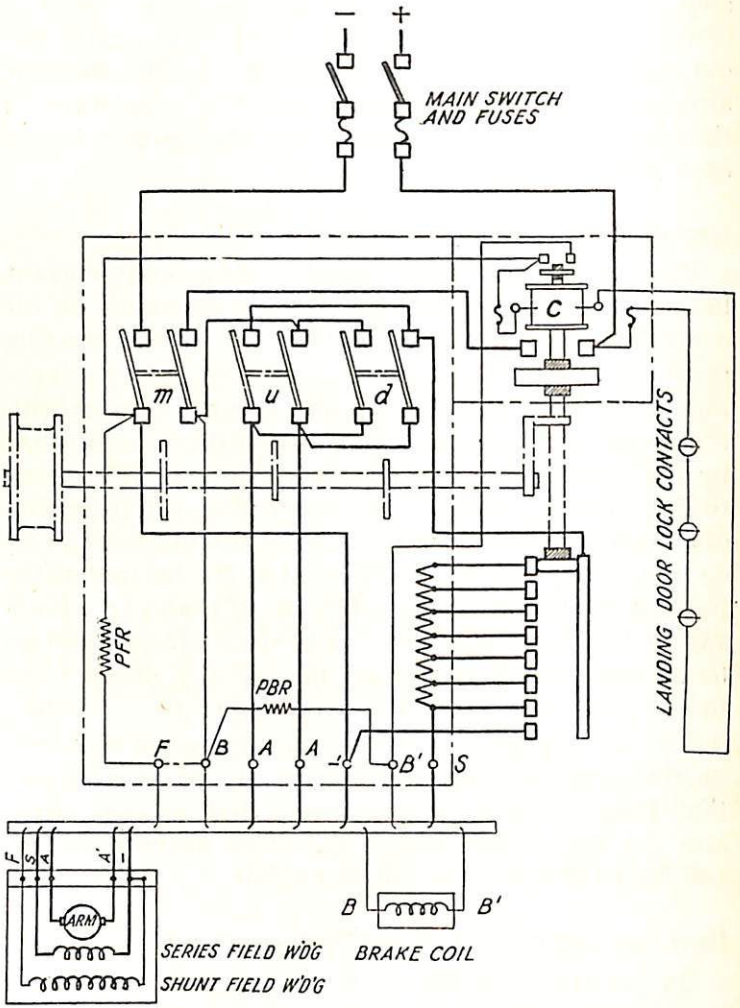



FIG. 72.—CONNECTIONS OF TYPICAL HAND-ROPE CONTROLLER, TOGETHER WITH MOTOR AND BRAKE.

of the accelerating switch is connected across the armature the contact arm (*d*) closes to cut out the first step of the starting resistance. As the motor continues to accelerate, the counter-e.m.f. increases accordingly, and in so doing it increases the magnetic flux between the switch arms and the magnet core until it is sufficient to close the second switch arm with its longer air gap and cut out the next step of starting resistance. Thus the switch arms are closed one after another as the armature gains speed, until the last arm closes to cut out the series field winding in the motor.

With this arrangement of accelerating switch the rate at which the starting resistance is cut out is dependent upon the load on the motor. Moreover, it is free from the difficulties associated with rheostats retarded by oil dashpots, in which the time taken to cut out the starting resistance is dependent upon the viscosity of the oil, which varies with the temperature.

## HAND-ROPE CONTROLLERS

It has already been mentioned that the hand-rope operated controller is equipped with a drum which, upon being rotated, actuates the various cam-operated switches for starting and reversing the lift motor. The rheostat for cutting out the starting resistance in the early types of these controllers is also operated mechanically. As the rope-drum is rotated from its central position to start the lift the rheostat arm is raised, thereby inserting the starting resistance, and when the rheostat arm is in its highest position the controller cams close the main and reversing switches

to apply power to the motor and release the brake. As soon as these switches close the rheostat arm is released, and in falling cuts out the starting resistance gradually and allows the motor to run at full speed, the rheostat arm being retarded in its fall by the action of a dashpot.

**Operation of Main Switches.**

The cam for operating the main switch (*m*) is so arranged that this switch closes for both directions of travel, but the cams for the switches (*u*—up) and (*d*—down) are so shaped that only one of these switches closes, according to the required direction of travel, when the rope-drum is rotated (Fig. 72).

**Purpose of Auxiliary Circuits.**

As the switches in a hand-rope controller are actuated mechanically they cannot be interlocked with the landing doors in the same manner as with electrically operated contactors, and it therefore becomes necessary to employ auxiliary equipment for preventing the lift from being operated unless the landing doors are closed.

Moreover, with a mechanically operated controller it is possible for the switches to be left in the "closed" position with the power supply to the motor cut off; as soon as the power supply is restored the car would start. Such a condition would not be harmful to the motor if the controller were provided with an electro-magnetic rheostat, because the starting resistance would be inserted automatically at the time the power supply was interrupted, but with a mechanically operated rheostat the starting resistance would be cut out, and full voltage would therefore be applied to the stationary armature.

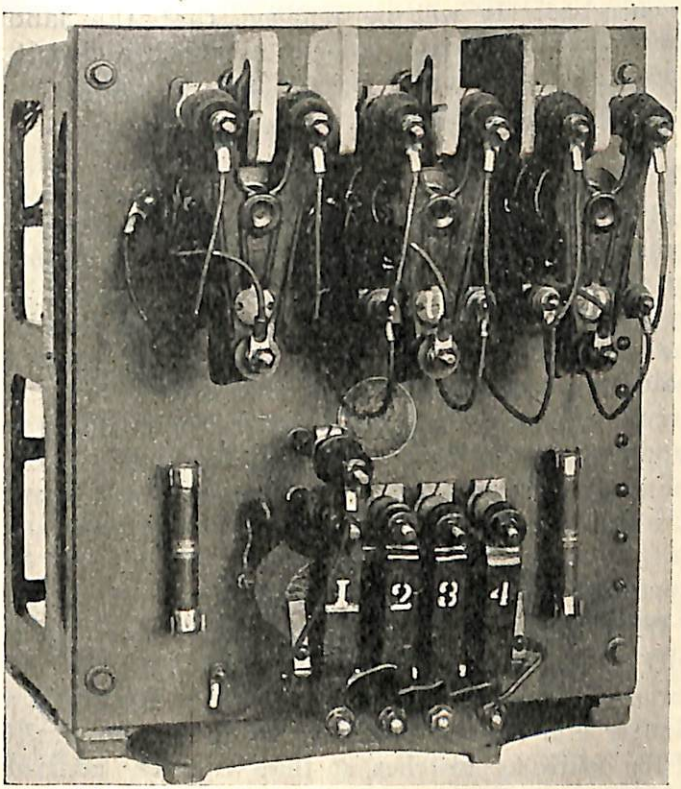



FIG. 73.—CONTROLLER FOR SINGLE-SPEED CAR-SWITCH OPERATED LIFT.
This has two reversing contactors, one main line contactor, and one accelerating switch (multiple contactor).

**Purpose of Main Line Contactor.**

The two difficulties just cited can be overcome by furnishing a main line contactor (*c*) connected as shown. It will be observed that its operating coil is in series with the landing-door lock contacts, and its contacts open the motor and brake circuits when it is

de-energised. It will be realised that the landing doors must be closed in order to establish a circuit for closing the main line contactor and so complete the motor and brake circuits.

**The Rheostat Arm.**

By arranging the main line contactor to operate in conjunction with the rheostat arm, which is actuated by the reversing switch cam shaft, it is possible to ensure that whilst the failure of the power supply or the snatching open of a landing door will cause the main line contactor to open the motor and brake circuits and stop the lift, the restoration of the power supply or the closing of a landing door will not cause the main line contactor to close unless the controller is returned to the "off" position and the lift restarted.

**Operation of Main Line Contactor.**

When the contactor is de-energised its switch arm falls on to the above-mentioned rheostat arm, which varies the length of the air-gap between the contactor plunger and its pole-piece according to the position of the controller switches, so that when the controller is in the "off" position the air-gap is less than when it is in the "on" position. The ampere-turns of the contactor coil are such that the resulting magnetic flux is sufficient to close the contactor with the reduced air gap but is insufficient to close it with the larger air gap, owing to the increased reluctance, and the lift attendant is therefore compelled to operate the hand-rope to return the controller to the "off" position and so insert the starting resistance before the lift can be restarted.

## CAR-SWITCH CONTROLLERS (SINGLE-SPEED)

The essential contactors on a controller for a single-speed car-switch operated lift are two reversing contactors and one multiple contactor, or accelerating switch.

The schematic diagram in Fig. 74 shows the main and operating circuits of a single-speed car-switch operated lift. The operating coils and the main contacts of the contactors are identified by capital letters, and the auxiliary contacts by the corresponding letters in italics.

### Operation of Car-switch Handle.

Commencing with the operating circuits shown in the upper part of Fig. 74, it will be seen that the circuits for the reversing contactor and, in turn, the main line contactor is completed, by moving the car-switch handle; movement of the car-switch handle in one direction causes the "up" contactor to close, and in the other direction the "down" contactor closes. Assuming that the car-switch handle is moved for the "up" direction, circuit is established from the positive operating fuse through the overspeed car-governor contacts of the car safety mechanism, emergency stopping switch in the car, landing-door lock contacts, car-gate contact, car-switch contacts, "up" stopping limit switch, operating coil (A) of "up" reversing contactor, interlock contact (*b*) of "down" reversing contactor, contact (*d*) of accelerating switch, and then to the negative operating fuse.

### Starting the Car.

The closing of the reversing contactor (A) completes

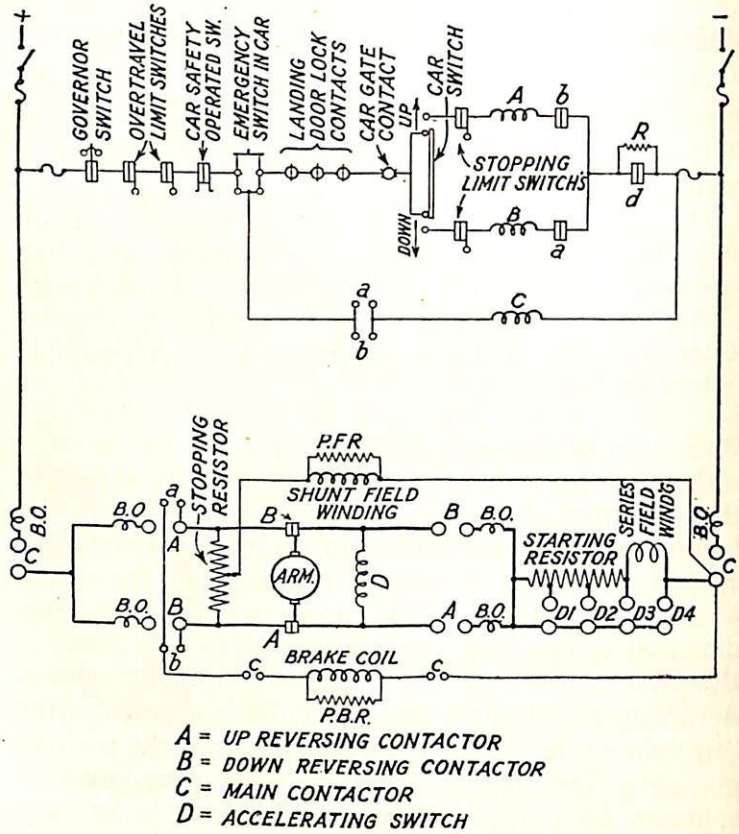



FIG. 74.—MAIN AND OPERATING CIRCUITS OF A SINGLE-SPEED CAR-SWITCH OPERATED LIFT.

The operating circuits are shown at the top. The operating coils and main contacts are identified by capital letters and auxiliary contacts by corresponding letters in italics.

the circuit for the operating coil of main contactor (C) through its auxiliary contacts (*a*), and thus the motor, brake, and shunt field are energised and the stopping resistance circuit is opened by the breaking contacts

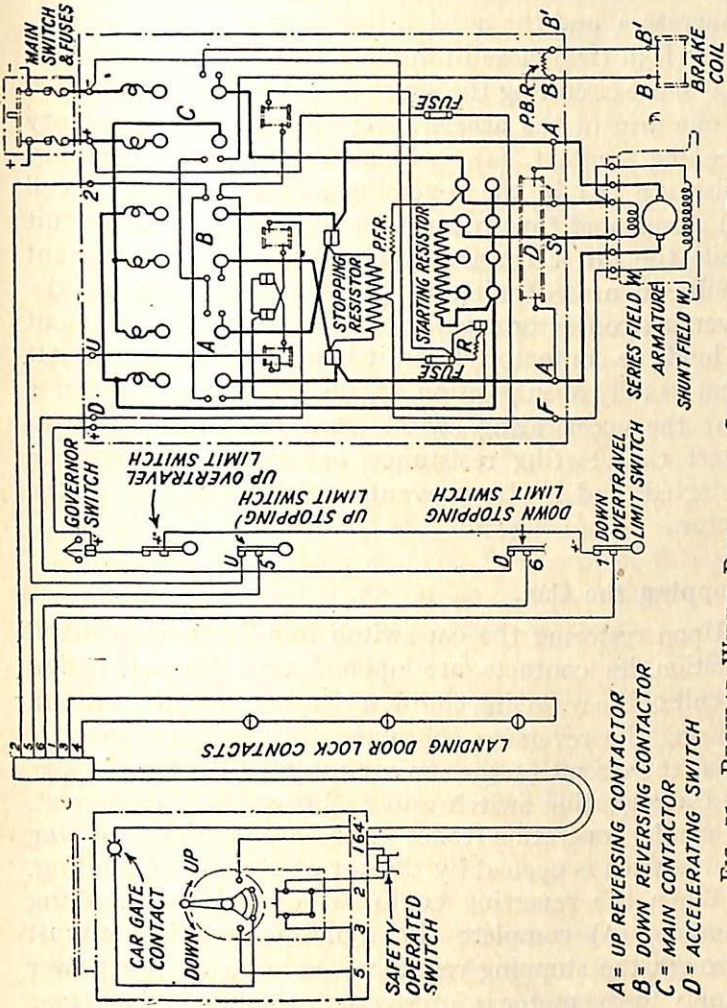



FIG. 75.—REGULAR WIRING DIAGRAM OF CIRCUITS SHOWN IN FIG. 74.
The above diagram would be used by the lift erector when wiring a lift installation.

(A). As the armature accelerates, the voltage across it increases, and the accelerating switch contacts (D1), (D2), (D3), (D4) close in numerical order, the last arm (D4) short-circuiting the series field winding. Attached to one arm of the accelerating switch is an auxiliary breaking contact (*d*), which inserts the auxiliary resistance (R) in the reversing switch operating coil (A) circuit and thus reduces the current in this circuit while the lift is running. This reduction in current results in a weakening of the magnetic flux of the reversing contactor magnet, and whilst it is sufficient to hold the contactor closed it is insufficient to close it from its fully open position. This arrangement ensures that the accelerating switch contacts must open to insert the starting resistance before the lift can be restarted, and it also prevents sudden reversal of the motor.

**Stopping the Car.**

Upon restoring the car-switch handle to its central position its contacts are opened and the operating circuit of the reversing contactor is thereby interrupted, causing the reversing contactor to open and in turn open the circuit of the main contactor, motor, brake, and accelerating switch and so bring the car to rest. A similar operation takes place when the stopping limit switch is opened by the car at the upper landing.

When the reversing contactor opens, its breaking contacts (A) complete the dynamic braking circuit through the stopping resistor. As soon as the power supply to the motor is interrupted, the motor functions as a generator, being driven by the kinetic energy of the lift, and thus this kinetic energy is converted into

electrical energy by the motor and lost as heat dissipated by the stopping resistor. The stopping of a lift using a D.C. motor is therefore effected by the combination of electrical braking by the motor and mechanical braking by the brake.

**The Regular Wiring Diagram.**

The wiring diagram shown in Fig. 75 is known as a regular wiring diagram; it incorporates the same circuits as shown in Fig. 74, but is laid out in a representative form and is used by the lift erector when wiring a lift installation.

It will be noticed that the shunt field winding is provided with a parallel resistor (p.f.r.) and the brake coil with the resistor (p.b.r.). The purpose of these resistors is primarily to provide a path for the induced e.m.f. caused by the collapse of the magnetic flux when the applied e.m.f. is interrupted; if a path were not provided, the voltage of this induced e.m.f. might reach a sufficiently high value to puncture the insulation surrounding the coil. The resistor (p.b.r.) also allows the induced current to circulate through the brake coil in the same direction as that due to the applied e.m.f., and the gradual decrease of the magnetic flux results in smooth application of the brake shoes.

**Overtravel Limit Switch.**

In the event of the car overrunning a terminal landing, an overtravel limit switch is opened which causes not only the reversing contactor but also the main contactor to open, thus ensuring that the power supply to the motor and brake is cut off and the car

brought to rest. A similar stop would be made upon operation of any of the other protective devices.

## TWO-SPEED CAR-SWITCH CONTROLLERS

Two-speed operation with a D.C. motor is readily secured by reducing the magnetic field of the motor, provided the motor is designed for running at two speeds.

### Two-speed Operation (Fig. 76).

When the car-switch handle is moved to the extreme right or left, the fast-speed contacts are closed, and the fast-speed contactor is thereby energised, and in opening its contacts it inserts the resistance (s.f.r.) in the circuit of the shunt field winding, and the resulting reduction in current in the field winding weakens the magnetic flux and so increases the motor speed. By opening the fast-speed contacts in the car switch, or allowing the car to travel to a terminal floor and so open the slowing limit switch, the fast-speed contactor is de-energised, causing the resistance (s.f.r.) to be short-circuited, and the resulting increase in magnetic flux produced by the shunt field winding reduces the motor speed and thus enables more accurate floor stopping to be obtained.

### Additional Shunt Field Winding for Slow Speed.

As already mentioned under D.C. motors, a reduced speed can be obtained by the use of resistors connected as shown in Fig. 79, the contactors for switching these resistors being of the type illustrated in Fig. 70, but, as previously explained, such methods of slowing should

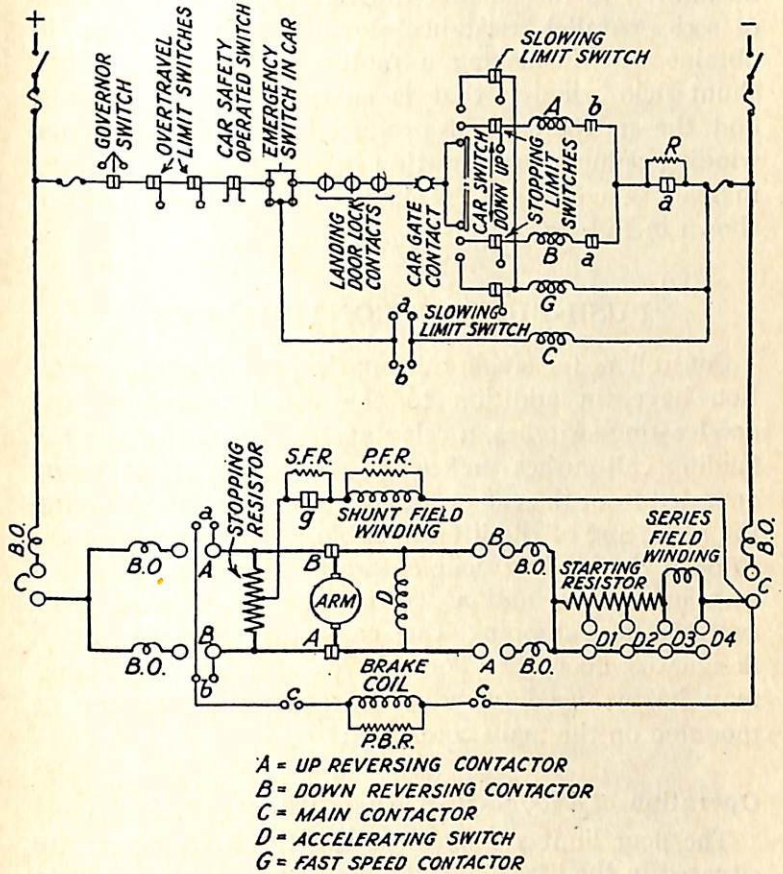



FIG. 76.—SCHEMATIC DIAGRAM FOR 2-SPEED, CAR-SWITCH OPERATED LIFT.

It will be noticed that 2-speed operation requires the addition of a fast speed contactor on the controller, additional contacts in the car switch, and a limit switch at the top and bottom of the lift well.

be limited to the smaller duties. An improved form of series-parallel resistance slowing, however, can be obtained by furnishing a motor with an additional shunt field winding that is energised when slowing, and the magnetic field produced by the additional winding reduces the variation in speed due to changes in load; a controller employing this arrangement is shown in Fig. 77.

## PUSH-BUTTON CONTROLLERS

Controllers for single automatic push-button operation have, in addition to the usual reversing and accelerating switches, a relay system for rendering the landing call-pushes ineffective when the lift is being operated from the car pushes, a time relay for delaying the restarting of the lift to enable a waiting passenger to open the landing door before the lift can be called to another floor and a set of floor relays and limit switches for stopping the car automatically at a designated floor; the floor relays and limit switches may be arranged as a separate floor controller or mounted on the main controller.

### Operation of Floor Limit Switches.

The floor limit switches for the terminal floors are situated in the lift well, but those for the intermediate floors are mounted on the floor controller and are operated by means of a chain drive from either the lift machine shaft or an auxiliary drum. When the floor controller is driven from the machine shaft it is necessary to make provision to maintain proper relation between the floor limit switches and the floors

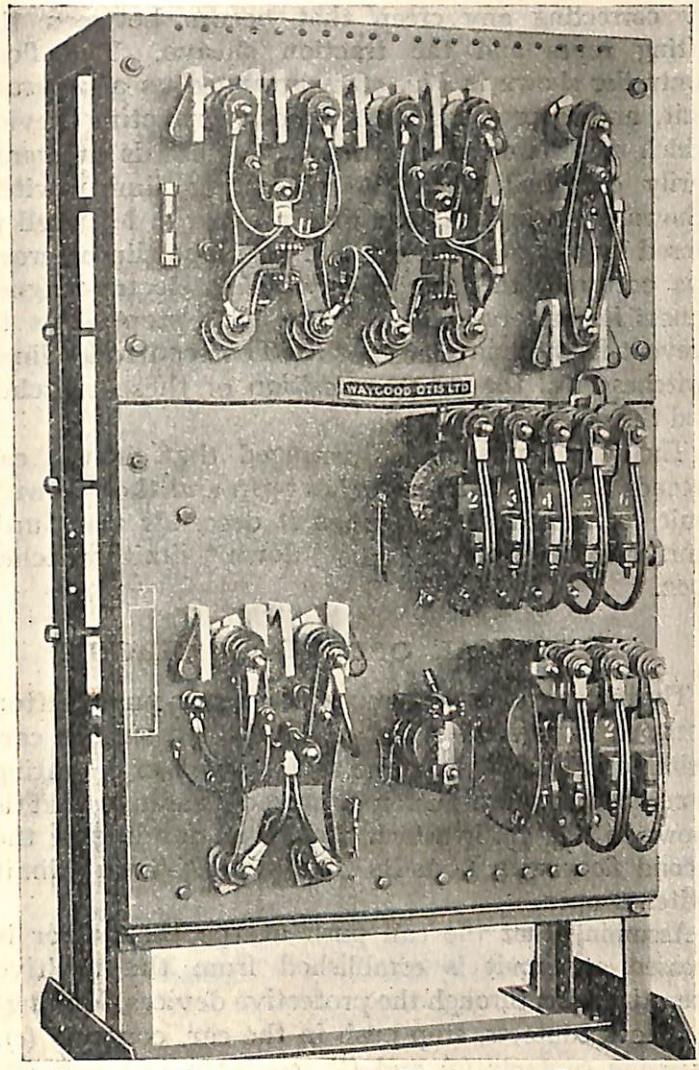



FIG. 77.—CONTROLLER FOR HEAVY-DUTY CAR-SWITCH OPERATED LIFT.

by correcting any creep that occurs between the lifting ropes and the traction sheave. The floor controller shown in Fig. 78 is arranged as a separate unit, and is provided with a floor correcting device which consists of an electro-magnet that is momentarily energised when the correcting limit switch (shown in wiring diagram Fig. 79) in the left well is closed by a cam on the car. If any rope slip or creep has occurred, the energising of this electro-magnet causes its armature to engage with a stop so as to prevent further movement of the floor controller limit switches until the relative position of these switches and the floors is corrected.

The floor limits are so arranged that as the car ascends the "up" limit switches open and the "down" limit switches close, and when it descends the "up" limit switches close and the "down" limit switches open.

## A TYPICAL OPERATING CIRCUIT

The motor and brake circuits of a single push-button operated lift are the same as those for a similar car-switch operated lift, and one arrangement of operating circuits for a push-button operated passenger lift is shown in Fig. 79, in which the car is standing at the second floor with both its "up" and "down" limit switches open.

Assuming that the call push at the third floor is pressed, a circuit is established from the positive operating fuse, through the protective devices, landing-door lock contacts, stop push in the car, contacts (*e*), reversing contacts (*a*) and (*b*), contacts (*f*) and (*e*), car-floor switch, third-floor call push, floor relay coil

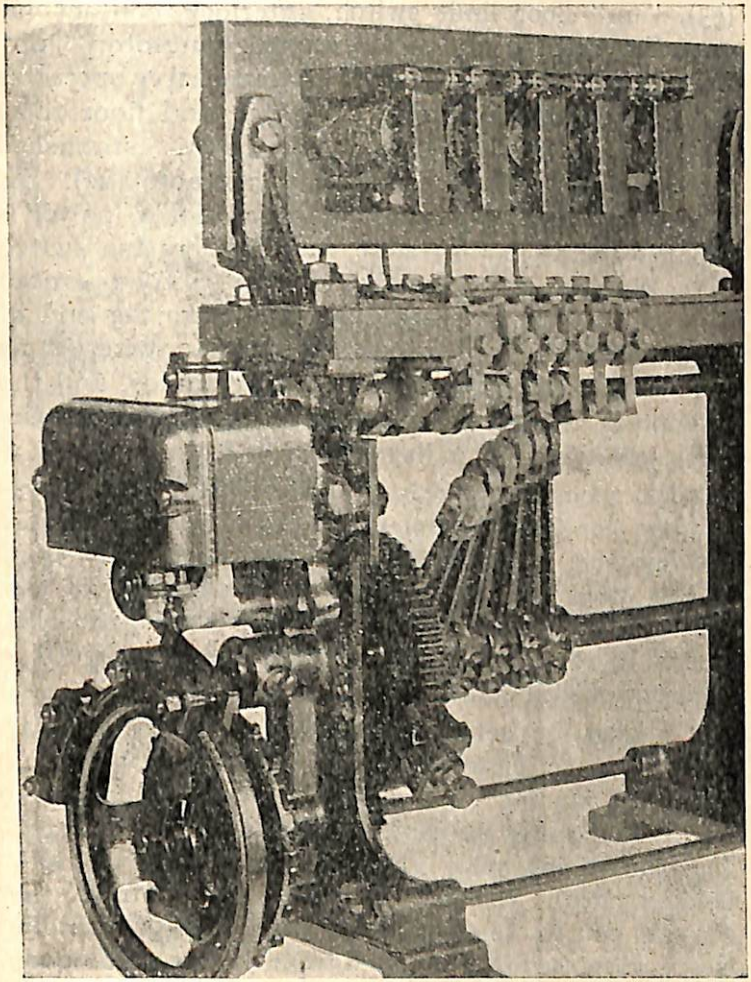


FIG. 78.—FLOOR CONTROLLER FOR SINGLE-SPEED, PUSH-BUTTON OPERATED LIFT.

This has one floor relay for each floor served and two sets of limit switches: one set is for stopping the car when ascending and the other set for stopping the car when descending. The floor-correcting device will be seen on the left of the controller.

(*g*3), "up" floor limit switch, interlock contact (*b*), operating coil (A) of "up" reversing contactor, "up" limit switch in lift well, contact (*d*) to negative operating fuse. The "up" reversing contactor and floor relay (*g*3) close and are held close by the circuit established by the closing of the floor relay contacts (*g*3). As soon as the "up" reversing contactor closes, power is supplied to the motor, brake, and accelerating switch in the same manner as described for car-switch operated lifts. It will be observed that the operating coil of the time relay (F) is fed from the same contacts (*a*) as the magnet coil of the floor correcting device, and the opening of the reversing contacts (*a*) interrupts the feed to the car and landing pushes.

When the car approaches the third floor the corresponding "up" limit switch opens and thus de-energises the reversing contactor (A) and the floor relay (*g*3), and so stops the car. Owing to the closing of the contacts (*f*) being delayed by a dashpot, the lift cannot be restarted from a landing call push until a predetermined time has elapsed.

A person, on entering the car, depresses the car floor and in so doing actuates the floor switch, which opens the landing push circuit, closes the car push circuit, and causes the car-holding relay (E) to operate. The car-holding relay (E) completes its own self-holding circuit, removes the short-circuit from the car-gate contact to ensure that the car gate must be closed when the lift is operated from the car, and opens the landing call-push circuit. The pressing of a car button then results in a similar sequence of operations to that described for landing operation.

The passenger, on leaving the car, opens the landing-

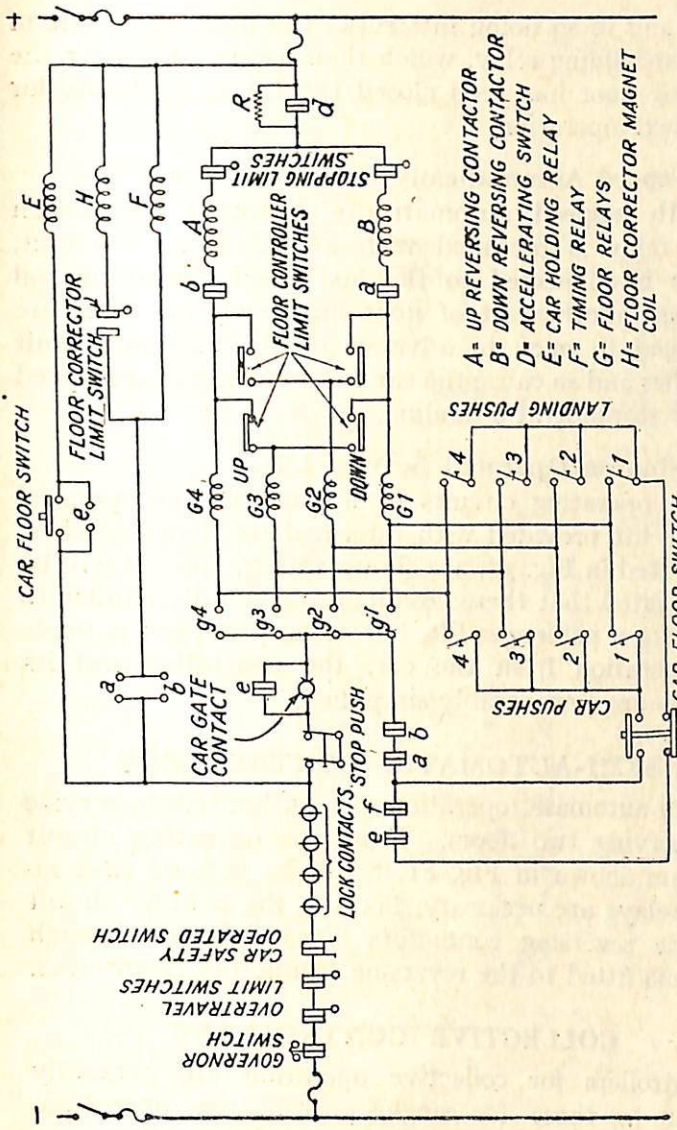



FIG. 79.—ARRANGEMENT OF OPERATING CIRCUITS FOR A PUSH-BUTTON OPERATED PASSENGER LIFT. Note that car is standing at the second floor with both its "up" and "down" limit switches open.

door and in so doing interrupts the holding circuit of the car-holding relay, which then opens, and after the landing door has been closed the lift is available for the next operation.

**Two-speed Automatically Operated Lifts.**

With 2-speed automatically operated lifts, each floor relay is provided with an additional contact, which is connected to the fast-speed contactor coil through another set of floor limit switches that are arranged to open in advance of the stopping limit switches and so cause the car to run at a reduced speed before stopping at a landing.

**Push-button Operated Service Lift.**

The operating circuits of a push-button operated service lift provided with intermediate floor switches, illustrated in Fig. 51, are shown in Fig. 80. It will be appreciated that these circuits are generally similar to those for a passenger lift, but as no provision is made for operation from the car, the controller and its circuits are considerably simplified.

## SEMI-AUTOMATIC CONTROLLERS

Semi-automatic operation is now limited to service lifts serving two floors. From the operating circuit diagram shown in Fig. 81 it will be noticed that no floor relays are necessary, because the holding circuit for the reversing contactors is established through contacts fitted to the reversing contactors themselves.

## COLLECTIVE CONTROLLERS

Controllers for collective operation are generally similar to those for single push-button operation,

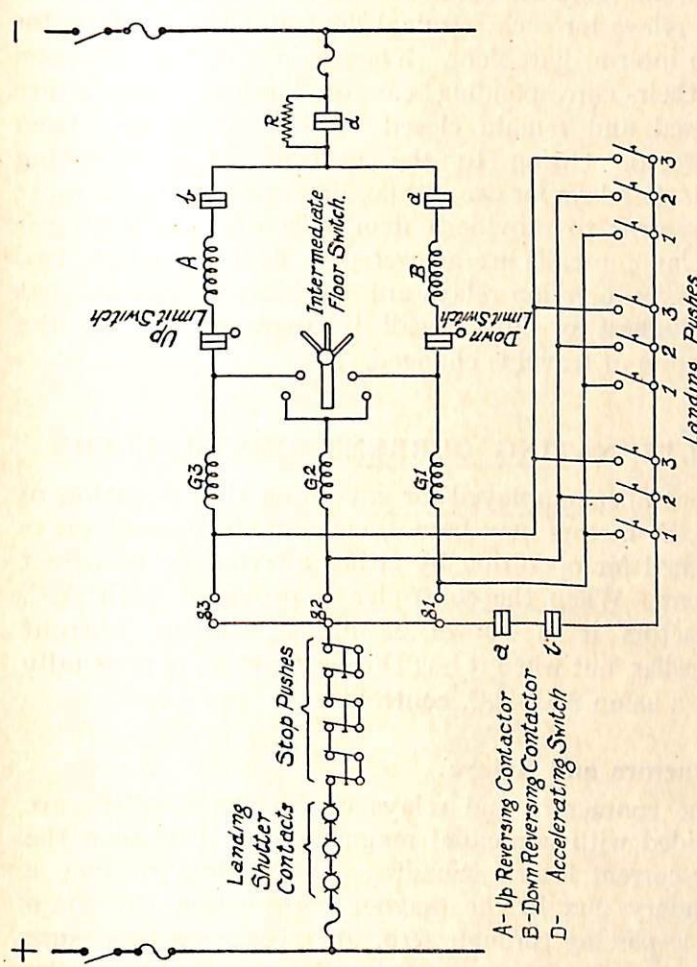



FIG. 80.—OPERATING CIRCUITS OF A PUSH-BUTTON OPERATED SERVICE LIFT PROVIDED WITH INTERMEDIATE-FLOOR SWITCHES.

excepting that the floor controller must be provided with one relay for each car and landing push, that is, two relays for each terminal floor and three relays for each intermediate floor. These relays operate as soon as their corresponding car or landing pushes are pressed and remain closed until the call has been answered. Owing to the necessity for providing separate relays for car and landing operation it is more convenient to provide a floor selector. As both car and landing calls are answered in floor sequence, two auxiliary direction relays are necessary to ensure that the highest or lowest call is answered before the direction of travel is changed.

## ALTERNATING CURRENT CONTROLLERS

Controllers employed for governing the operation of A.C. lift motors may have their contactors and relays designed for operation by either alternating or direct current. When the controller is provided with A.C. contactors it is known as an alternating current controller, but when it has D.C. contactors it is usually known as an A.C.-D.C. controller.

### Contactors and Relays.

The contactors and relays of A.C. controllers are provided with laminated magnet cores to reduce the eddy-current losses. Shading coils, which produce a secondary flux in the magnet cores while the main flux is passing through zero, are necessary to ensure that a continuous magnetic pull exists between the magnet cores while the contactor is energised. The slamming of medium- and heavy-duty A.C. contactors

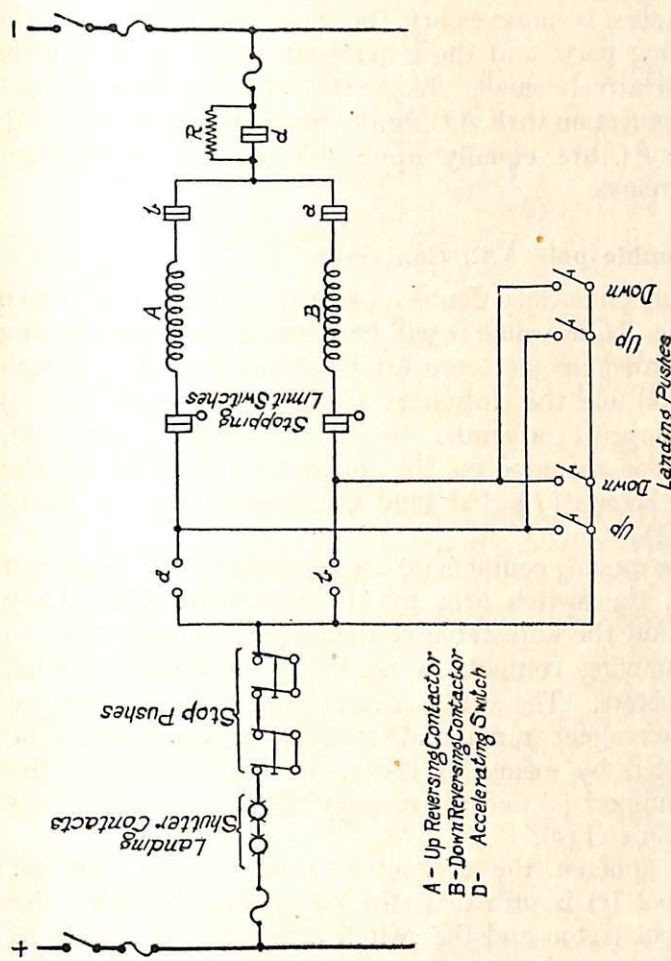



FIG. 81.—OPERATING CIRCUIT DIAGRAM OF SEMI-AUTOMATIC SERVICE LIFT SERVING TWO FLOORS.

can be minimised by the provision of an air dashpot. For the smaller contactors and relays the use of air dashpots is unnecessary, because the inertia of the moving parts and the movement of the switch arms are relatively small. In general, the details explained in connection with A.C. brake magnets in Chapter III, page 83, are equally applicable to A.C. contactors and relays.

**A Double-pole A.C. Contactor.**

A medium-duty double-pole A.C. contactor is shown in Fig. 82, in which it will be noticed that the moving laminated magnet core (*a*) is clamped in the switch arm (*b*) and the stationary laminated magnet core (*c*) is clamped in a similar way to the magnet frame (*d*), which is mounted on the controller panel (*e*) by the same screws (*f*) that hold the base of the air dashpot (*g*).

The moving contacts (*h*) are carried by, but insulated from, the switch arm by the insulators (*k*). They close on the adjustable contacts (*m*). Connection to the moving contacts is made by insulated flexible connectors. The switch arm is hinged at the bottom of the magnet frame, and its radial movement can be adjusted by means of the screw (*n*). Between the coil support (*o*) and the magnet frame is mounted the magnet coil (*p*).

To quieten the contactor when closing, an air dashpot (*g*) is provided; the connection between the dashpot piston and the switch arm takes the form of a rod (*q*) and the retarding effect of the dashpot can be regulated by means of the screw (*r*) in the valve (*s*). When the contactor is de-energised the piston and

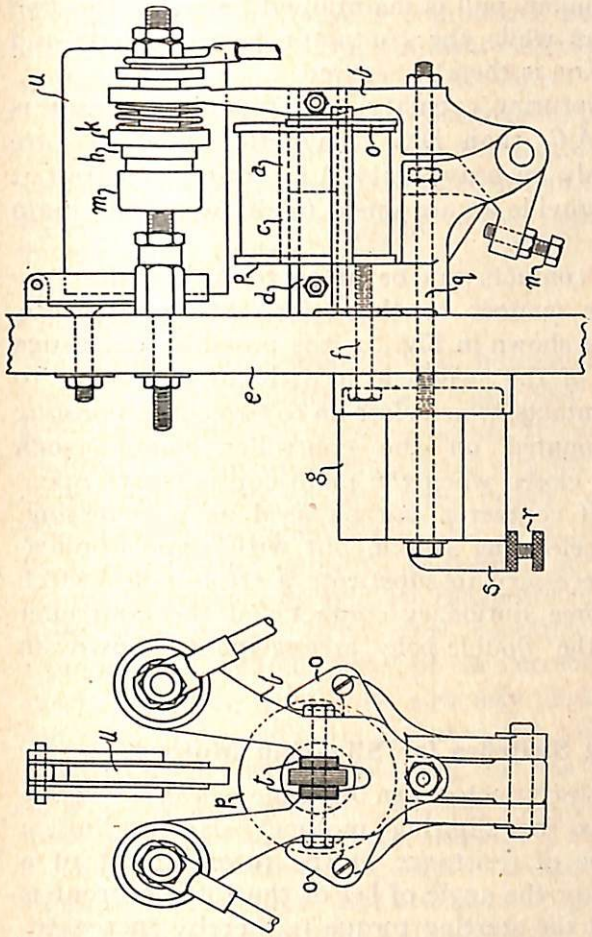



FIG. 82.—A MEDIUM-DUTY DOUBLE-POLE A.C. CONTACTOR.
Moving laminated magnet core (*a*). Switch arm (*b*). Stationary laminated magnet core (*c*). Magnet frame (*d*). Controller panel (*e*). Screws (*f*). Air dashpot (*g*). Moving contacts (*h*). Insulator (*k*). Adjustable contacts (*m*). Switch-arm adjusting screw (*n*). Coil support (*o*). Magnet coil (*p*). Rod (*q*). Dashpot regulator screw (*r*). Valve (*s*). Shading coils (*t*). Arc shield (*u*).

its operating rod are returned to their normal position by means of a compression spring in the dashpot. Surrounding the outer sets of laminations are the shading coils (*t*), which, as previously explained, ensure

that a continuous pull is maintained between the two magnet cores while the contactor is energised, and quiet operation is thereby secured.

As the rupturing capacity of a given contactor is higher for A.C. than D.C., magnetic blow-outs are necessary only on heavy-duty A.C. contactors, but it is usual to provide an arc shield (*u*) between the main contacts.

Auxiliary contacts can be fitted to A.C. contactors in a similar manner to those for D.C. contactors. With the one shown in Fig. 82 it is possible to arrange the bottom of the switch arm with an extension to carry two contacts, which close on to two corresponding contacts mounted on the controller panel; such contacts are closed when the main contacts are open. This type of contactor can be used as a reversing, main, or accelerating switch, but with some applications it is necessary to substitute a triple-pole switch arm with three stationary contacts on the controller panel for the double-pole arrangement shown in Fig. 82.

**Accelerating Switches for Slip-ring Motors.**

Double-pole contactors can be employed as accelerating switches for slip-ring motors. By adding a certain value of resistance to the rotor circuit of a slip-ring motor the angle of lag of the rotor current is reduced and the starting torque is thereby increased, but too much added resistance, however, will reduce the torque, because the current will be excessively reduced. It will be noticed in Fig. 83 that the accelerating contactor operating coils are so connected that after the last accelerating contactor has closed, its

auxiliary making contacts complete a holding circuit and its auxiliary breaking contacts interrupt the circuit of the other accelerating contactor coils.

With a high-torque squirrel-cage motor, the starting resistance must be inserted in the stator circuit, and whilst 2-pole accelerating contactors can be used for a 2-phase motor it is necessary to use 3-pole contactors for a 3-phase motor.

**Phase-failure Relays.**

Although not essential for normal operation, a most desirable addition to a controller governing a polyphase motor is a phase-failure relay. It will be realised that the operating circuit of a lift is connected across one of the phases of the power supply, and if the other phase should fail, due to a blown fuse or from some other cause, it is possible for the various controller contactors and also the motor to be energised from one phase. With this condition the motor cannot start, and the value of the current through the motor winding would be seriously high; moreover, with an automatically operated lift the contactors would be held closed, allowing this heavy current to flow for a long period. Such a contingency can be prevented by the use of a phase-failure relay.

One form of this relay affords protection not only against phase-failure but also against phase-reversal, and it takes the form of a simple torque motor with a metal-disc rotor. When the relay is energised by more than one phase the rotor is rotated, and, in stalling, closes its contacts, but in the event of phase-failure or low voltage the rotor loses its torque, and in returning to its "off" position it opens its contacts

and interrupts the operating circuit, which in turn opens the power supply to the lift motor. Should phase-reversal occur in the power supply to the lift, the rotor of the reverse-phase relay would be rotated in the opposite direction, and its contacts thereby opened; operation of the lift is thus prevented. The need for protecting a lift against accidental phase-reversal is self-evident.

**Low-voltage Operating Circuits.**

With some methods of automatic operation it is convenient to use a lower voltage for the operating circuits, and this lower voltage can usually be obtained with 3-phase power supplies by taking advantage of the neutral wire; with a 400-volt, 3-phase, 4-wire supply the motor would operate on the 400-volt supply and the operating circuits would have a 230-volt supply.

With a single-phase power supply, or where the neutral wire is not available, the lower voltage can be obtained by using a single-phase step-down transformer.

**A.C.-D.C. Controllers.**

It will be appreciated that when D.C. contactors and relays are employed on controllers governing A.C. motors the main and operating circuits will be generally similar to those for lifts employing controllers provided with A.C. contactors and relays. The D.C. power supply is obtained by means of a metal-oxide rectifier or a small motor-generator set.

**Hand-rope Controllers.**

Hand-rope controllers for A.C. power supplies are generally similar to those for D.C., excepting that

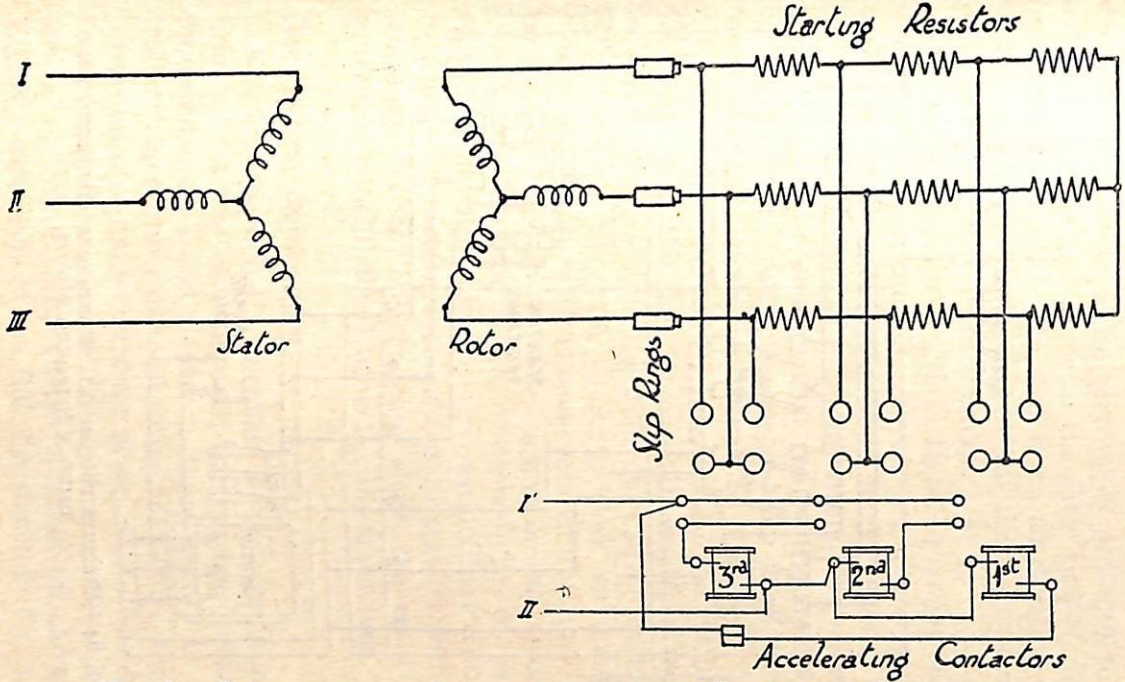



FIG. 83.—CONNECTIONS FOR SLIP-RING MOTOR USING DOUBLE-POLE CONTACTORS AS ACCELERATING SWITCHES.

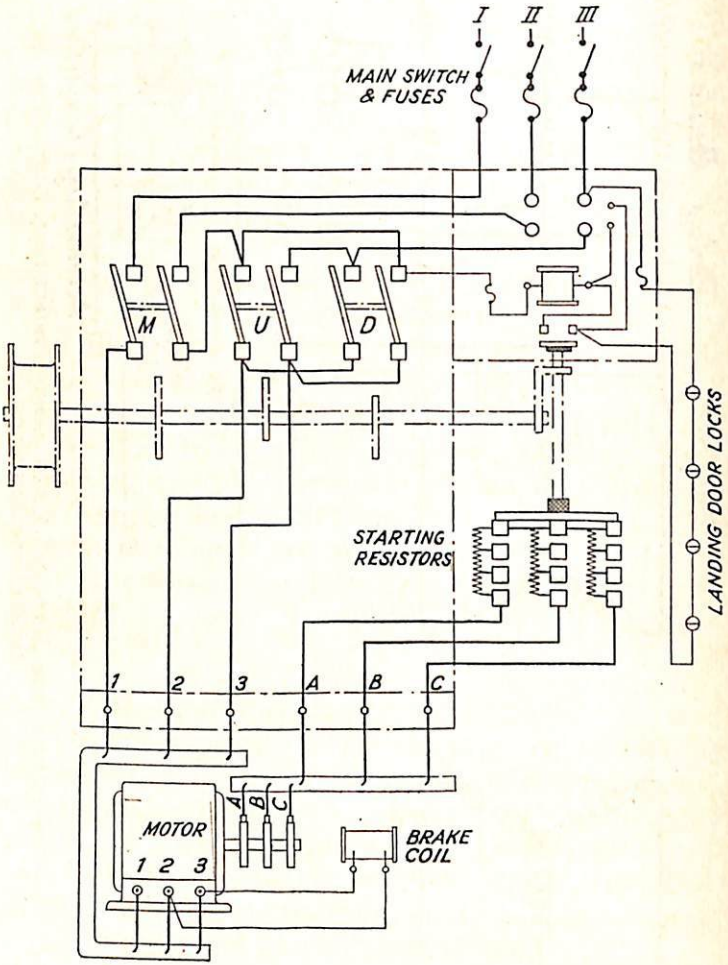



FIG. 84.—CIRCUITS FOR AN A.C. HAND-ROPE OPERATED LIFT USING A SLIP-RING MOTOR.

with slip-ring motors the rheostat is arranged to cut out the starting resistance in the rotor circuit. With high-torque squirrel-cage motors an accelerating contactor can be employed to cut out the starting resistance inserted in the stator circuit.

It was explained under "D.C. Hand-rope Controllers" that a main line contactor, operating in conjunction with the switch cam shaft, could be provided to stop the lift in the event of a landing door being snatched open, and it also ensures that the controller must be restored to the "off" position and the starting resistance inserted before the lift can be restarted. With A.C. the same method of interlocking the main line contactor with the switch cam shaft would, of course, be unsatisfactory, but the difficulty can be overcome by arranging the cam shaft to close an auxiliary switch as the cam shaft is being rotated from the "off" to the "on" position. The closing of this auxiliary switch completes the circuit for the main line contactor, which, upon operating, closes its own auxiliary contacts. As these contacts are connected in parallel with the auxiliary switch on the cam shaft the main line contactor is held closed while the lift is running.

**Car-switch Controllers.**

A single-speed A.C. controller for car-switch operation has its two reversing and accelerating contactors mounted on a panel similar to those for a D.C. controller; the number of accelerating contactors, and the provision of a main contactor depends upon the duty. Comparing the schematic wiring diagram of a single-speed 3-phase A.C. car-switch operated lift shown in Fig. 85, with that of the D.C. lift shown in Fig. 74, it

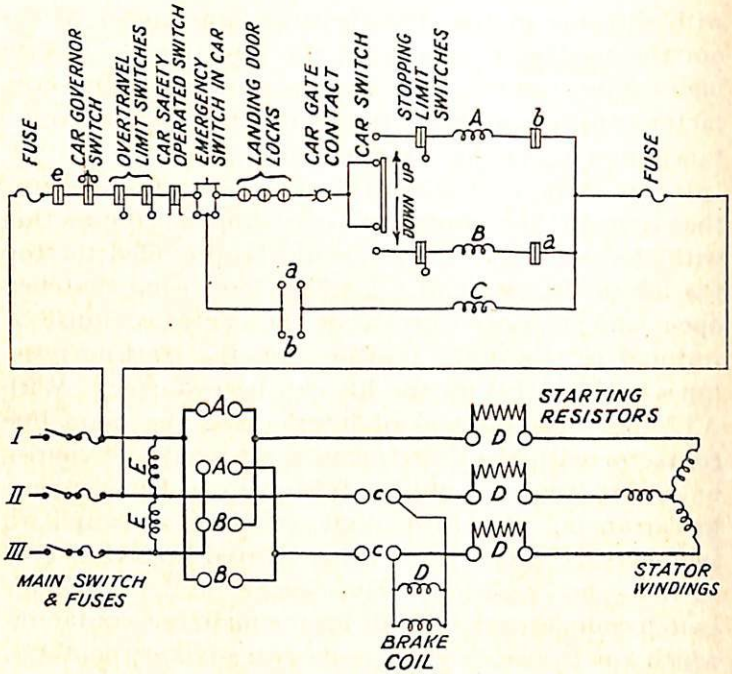



FIG. 85.—WIRING DIAGRAM OF A SINGLE-SPEED 3-PHASE A.C. CAR-SWITCH OPERATED LIFT.

will be noticed that the operating circuits are very similar, and the general sequence of operation already given for the D.C. lift will therefore apply.

With a single-phase A.C. brake it is possible to connect the brake coil between any two of the connections from the reversing switch to the motor, as shown in Fig. 85, but with a motor-operated brake it

is necessary to provide either a relay or additional contacts on the reversing contactors for the brake-motor circuit in order that the brake motor will rotate in the same direction to release the brake shoes for either direction of travel of the lift. The brake circuit of any type of brake should, however, be made subject to the main contacts of the reversing contactors to ensure that the brake is not released without power being applied to the motor.

Power is applied to the motor, brake, and accelerating contactor coil as soon as a reversing contactor closes; the closing of the accelerating contactor, however, is delayed by the action of its air dashpot. The coils of the phase-failure relay must of necessity be permanently connected across the mains, as shown in Fig. 85; the power consumption of the phase-failure relay is negligible, being a few watts per phase.

**Two-speed Car-switch Operated Lift.**

With a 2-speed, car-switch operated lift using a pole-changing motor, additional contactors are required to energise the slow-speed motor windings before stopping. Two-speed A.C. lift motors are usually provided with two separate stator windings, by which the number of poles and the running speeds are determined. The control circuits are so arranged that during the change from fast to slow speed the power supply to the motor is not interrupted.

Referring to the schematic wiring diagram of a 3-phase, 2-speed, car-switch operated lift with a pole-changing motor shown in Fig. 86, it will be noticed that when the car-switch handle is moved to, say, the extreme "up" position the "up" reversing contactor

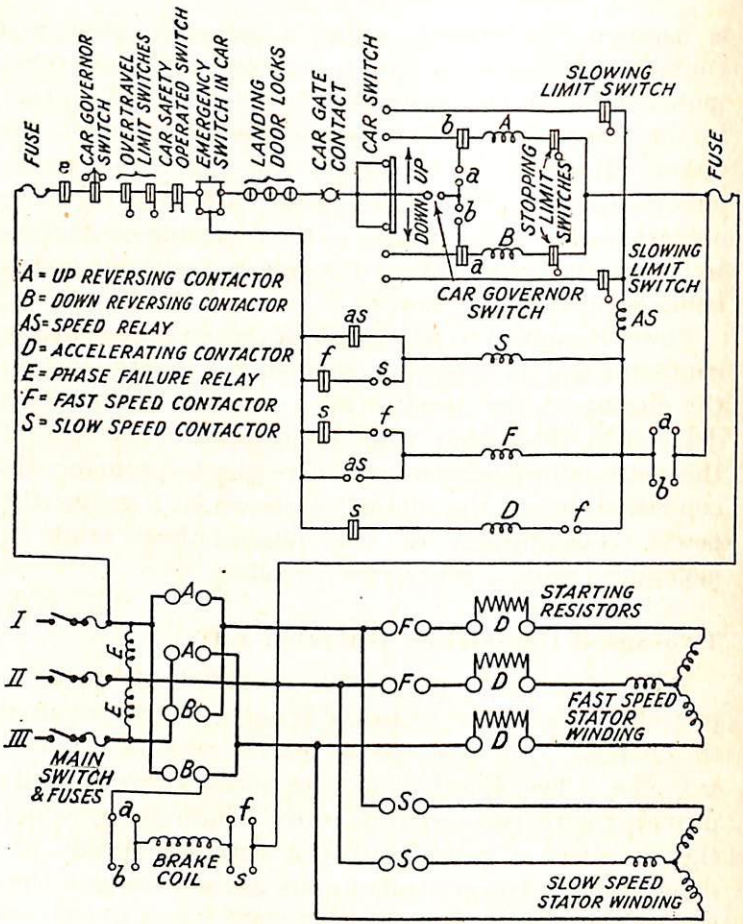



FIG. 86.—SCHEMATIC WIRING DIAGRAM OF A 3-PHASE, 2-SPEED, CAR-SWITCH OPERATED LIFT WITH A.C. POLE-CHANGING MOTOR.

(A) is energised; the closing of its contacts (*a*) permits the speed relay (AS), and, in turn, the fast-speed contactor (F) to close. As soon as the contacts (F) close, power is admitted to the fast-speed stator

winding. The brake and accelerating switch circuits are completed by the closing of the auxiliary contacts (*f*).

When the car-switch handle is moved to the slow-speed position, or the car approaches the top landing, the speed relay (AS) is de-energised, causing its breaking contacts (*as*) to close and its making contact (*as*) to open, and thus the slow-speed contactor (S) is energised and power is admitted to the slow-speed stator winding, causing the motor to run at slow speed. Upon centering the car-switch handle, or allowing the car to open the "up" stopping limit switch, the slow-speed contactor (S) and the reversing contactor (A) are opened and the power supply to the motor is cut off and the brake applied.

It will be noticed that the contacts (*as*), in both the fast and slow-speed contactor circuits, are provided with a parallel circuit; the parallel or holding circuit of contactor (F), in conjunction with the opening of the auxiliary breaking contacts (*s*), allows the closing of the contactor (S) to overlap the opening of the contactor (F), so that the power supply to the motor and brake is not interrupted during the change in speed. A similar condition exists with the closing of contactor (F) with respect to the opening of contactor (S).

In the event of the car-switch handle being moved quickly from the fast to the slow-speed position the opening of the reversing contactor is delayed, being held closed by its holding circuit through the governor switch contacts, and thus the slow-speed winding is energised and a powerful braking effort is produced. The closing of the slow-speed contactor (S) causes its

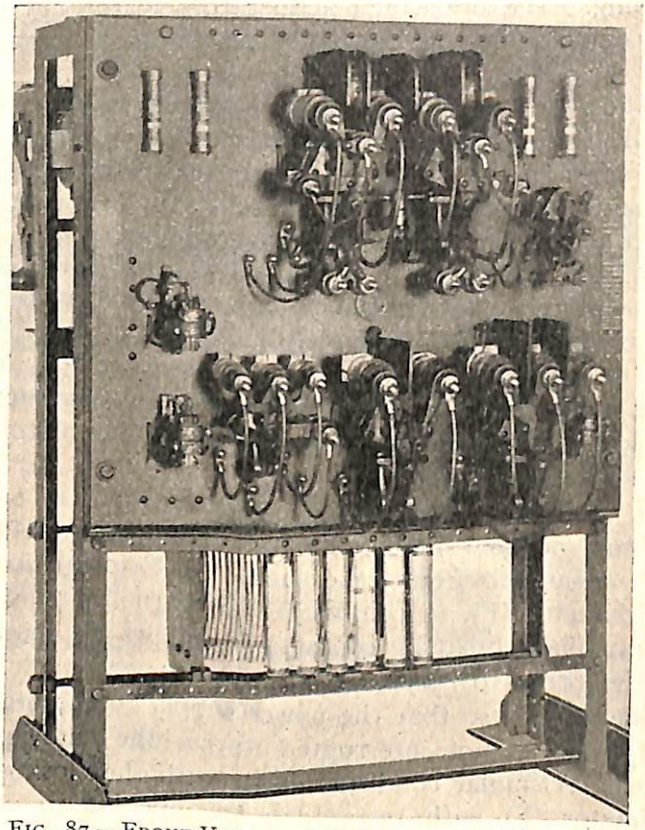


FIG. 87.—FRONT VIEW OF A.C. PUSH-BUTTON LIFT CONTROLLER.

At the top are the two reversing contactors and the time relay. The lower row of contactors comprises a double-pole main contactor and two 3-pole contactors for use as accelerating switches. There are also two car-hold relays and an auxiliary cam relay.

auxiliary contacts (*s*) to open the accelerating switch circuit and so insert the starting resistance.

**Push-button Controllers.**

From the description of D.C. controllers in general, coupled with what has been written on A.C. controllers, it will be realised that the operating circuits and sequence of operation of A.C. controllers for push-button, semi-automatic, and collective operation follows closely upon the wiring diagrams and descriptions already given for the various systems of automatic operation for D.C. power supplies.

Mounted at the top of the controller panel (Fig. 87) are the two reversing contactors, and to the right of them will be seen the time relay. The lower row of contactors comprises a double-pole contactor for use as the main contactor and two 3-pole contactors for use as accelerating switches. Because the last accelerating contactor to close carries a heavier current for a much longer period than the first accelerating contactor, it is correspondingly larger. Of the three remaining relays, two, in this instance, are used as car-hold relays and the other relay is known as the auxiliary cam relay, and it completes the circuits for the retiring cam, which, as explained, releases the landing door lock when the car stops at a floor.

The main starting resistors, together with the auxiliary resistors, will be seen mounted at the bottom of the controller frame.

CHAPTER VII

## VARIABLE-VOLTAGE CONTROL

THE term "variable-voltage control" is used in contradistinction to rheostatic control; with the former method of control the armature of the lift motor is connected to the armature of a generator of a motor-generator set, and the speed, acceleration, retardation and reversing of the lift are effected by varying the strength and polarity of the generator field, but with rheostatic control, acceleration and speed variation are secured by the use of resistors.

### High Speeds Possible.

Variable-voltage control has many advantages. It permits higher rates of acceleration and retardation without causing discomfort to the passengers and it has made car speeds of over 1,200 ft. per minute possible. The losses in the starting and bypass resistors used with rheostatic control are eliminated, and advantage can be taken of the inherent flexibility of control of D.C. motors, even with incoming A.C. power supplies.

With rheostatically controlled D.C. motors for geared lift machines it is more convenient to reverse the connections of the armature to change the direction of rotation, because the polarity of the series field must be the same as that of the shunt field and the reversing contactors must therefore be of sufficient

capacity to handle the main current. With variable-voltage control, however, the lift motor is shunt wound, and the reversing can be accomplished by changing the connection of the generator shunt field, and as the shunt field current is comparatively small the contactors on variable-voltage controllers are correspondingly smaller.

**The Principal Circuit.**

The principal circuits of a variable-voltage lift controller are shown in Fig. 88. in which it will be observed that the armatures of the generator and lift motor are permanently connected without any intermediate switchgear. For an incoming A.C. power supply the motor-generator set has an induction driving motor, and for D.C. power supplies a compound-wound motor is employed. The motor-generator set is constantly running while the lift is in service, and with an attendant-operated lift it is started and stopped from the car by the attendant, but with automatic systems of operation it is started and stopped automatically.

As the voltage of the generator must of necessity vary, it is essential to provide some auxiliary means to furnish a D.C. power supply of constant voltage for exciting the shunt field windings of the lift motor and generator and also for the controller and brake coils; this D.C. supply is usually obtained from an exciter mounted on the motor-generator set. Owing to the appreciable time-constant of the field of a gearless machine, the shunt field windings of such a machine are energised all the time the motor-generator set is running. The time-constant of the field is a measure

of the rate at which the current, and therefore the magnetic flux, increases, and is dependent upon the inductance and resistance of the field winding; the time taken for the magnetic flux of a gearless motor to reach its maximum value may be some seconds after the circuit of the field windings has been completed.

**Operation.**

Reference to the wiring diagram in Fig. 88 will show that the lift-motor field winding is connected across the power supply from the exciter and the generator shunt field circuit is completed by the closing of a reversing contactor through the resistors (GFR). Owing to these resistors, the generator voltage is low when a reversing contactor closes, and as the accelerating contactors (C), (D), and (E) close in alphabetical order to short-circuit these resistors (GFR), the generator field is strengthened and the voltage is consequently increased. Final speed is obtained by opening the contacts (F), which insert the resistance (MFR) and thereby weaken the lift motor field.

To retard and stop the lift, the lift motor field is first strengthened by short-circuiting the resistor (MFR), the resistors (GFR) are then inserted step by step by the opening of the accelerating contactors (C), (D), and (E) to weaken the generator field and so reduce the generator voltage until the generator field circuit is interrupted by the opening of the reversing contactor, and the brake is then applied.

Because of the time-constant of the generator field the change in strength of the generator magnetic flux lags behind the cutting in, or out, of the field resistors,

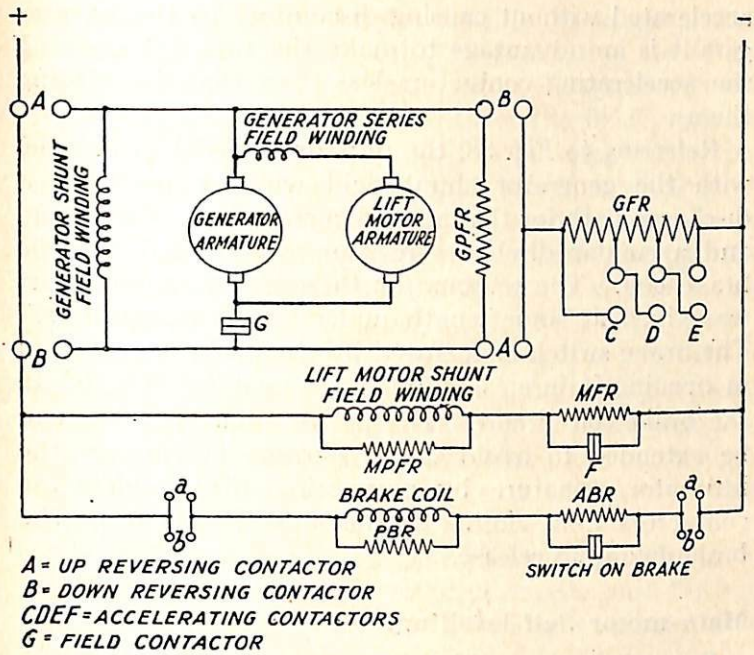



FIG. 88.—PRINCIPAL CIRCUITS OF A VARIABLE-VOLTAGE LIFT CONTROLLER.

and the consequent change in motor speed is therefore smooth and continuous.

Various methods are employed for varying the strength of the generator field, but the opening and closing of the accelerating contactors employed in the arrangement included in Fig. 88 are timed by means of inductances connected in series with the operating coils of these accelerating contactors, and by suitable switching these contactors close in a definite time sequence and open in a different time sequence. As a car can be retarded at a higher rate than it can be

accelerated without causing discomfort to the passengers it is an advantage to make the time for opening the accelerating contactors less than that for closing them.

Referring to Fig. 88, the resistor (GPFR) in parallel with the generator shunt field winding provides a discharge path for the induced current in this winding, and a similar discharge resistor is provided for the brake coil. The reasons for these discharge resistors was given at some length under "D.C. Controllers." The brake switch is operated by the brake levers, and in opening it inserts the cooling resistance (ABR) in the brake-coil circuit. The use of such switches can be extended to avoid heavy current flowing in the lift-motor armature by preventing the accelerating contactors from closing in the unlikely event of the brake failing to release.

**Main-motor Self-levelling.**

For main-motor self-levelling operation with variable-voltage control it is advisable to provide the generator with an additional shunt field winding for the levelling operation. This additional field winding produces a much weaker magnetic flux than the main field winding, and it ensures that the generator can deliver only a very low voltage, and consequently a very slow car speed is ensured for the self-levelling operation.

Owing to the residual magnetism in the generator it is possible for the generator to generate an e.m.f. while idling and so cause a current to circulate through the armature circuit of the generator and lift motor although the lift is at rest. As the direction of this circulating current depends upon the polarity of the

residual magnetism it is possible to destroy this residual magnetism by suitably connecting the shunt field winding of the generator across its armature when the lift is at rest. The polarity of the field produced by the generated e.m.f. will then be opposite to that of the residual magnetism and therefore destroy it, and under such conditions the generator cannot excite itself. The circuit between the generator shunt field winding and the generator armature is completed by the contacts (G) (Fig. 88) when the lift is stationary.

The advantages of variable-voltage control can be extended to geared machines by substituting a shunt wound lift motor for the usual compound-wound or induction lift motor, and the self-levelling feature can be obtained without the addition of the auxiliary levelling machine.

It will be appreciated that the various systems of operation, such as car-switch, automatic push-button, collective, signal, and the like, are available with variable-voltage control.

**Electric Car and Landing Door Operators.**

To take full advantage of high-speed lifts it is necessary to employ power-operated car and landing doors, and the electric door operator has been developed to supersede many pneumatic door operators.

The heavy-duty electric door operator consists of an electric motor, electro-mechanical brake, worm reduction gearing with two eccentrics, and limit switches suitably mounted and carried on a cross-head of the car frame. One eccentric is connected by means of a chain to the levers which operate the car doors. Another chain connects the other eccentric

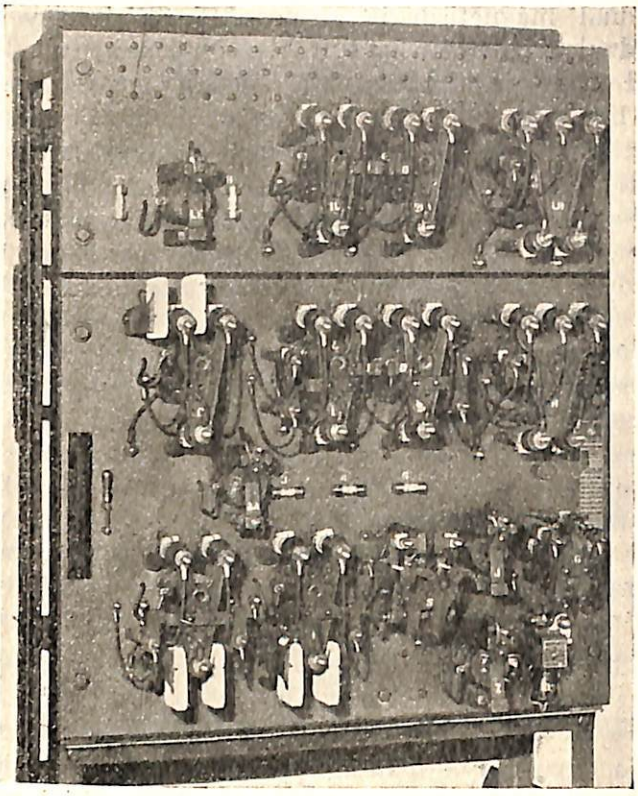


FIG. 89.—VARIABLE-VOLTAGE CONTROLLER FOR CAR-SWITCH OPERATION.

to a cam mounted at the side of the car, and the rotating of this eccentric imparts motion to the cam which, when extended, pressed against one leg of a bell-crank lever mounted on the landing sill, and the other leg is connected to the operating levers of the landing door by a push-rod.

The car and landing doors are thus opened by

power but are closed independently by individual spring pressure. As the doors approach their limits of travel when opening or closing they are cushioned by means of oil dashpots and the appropriate limit switch is opened, causing the power supply to the door-operating motor to be interrupted and the brake applied. The doors are at all times under the full control of the lift attendant and can, in an emergency, be manually operated.

A lighter type of electric door operator for medium-duty lifts also employs an electric motor, but the connection between the car and landing doors is made by a cam attached to the car doors so that the actual opening of the car doors imparts the necessary motion to the landing doors.

**Power Consumption.**

The power consumption of a lift is usually expressed in full-load round trips per k.w.h., that is, the number of times a car carrying contract load will ascend from the lowest to the uppermost floor and return for the consumption of 1 k.w.h. With variable-voltage controlled lifts, however, the idling current of the motor-generator set will offset some of the saving effected by the elimination of rheostatic losses. Moreover, the greater the number of stops per car mile the higher will be the consumption even for the same loading conditions. The effect of regenerative braking is an important but variable factor.

Another factor which considerably affects the power consumption of some lifts is the skill of the lift attendant in stopping the car level with the floor; if he starts and stops several times in inching the car to floor-level

the consumption will be greatly increased. In this connection self-levelling lifts are an advantage. Frictional losses are variable, even for similar installations, and these losses are an important factor with geared equipment.

From the foregoing it will be appreciated that the calculation of power consumption becomes empirical, and some of the data employed may vary widely from conditions found in practice.

## CHAPTER VIII

# MAINTENANCE OF ELECTRIC LIFTS

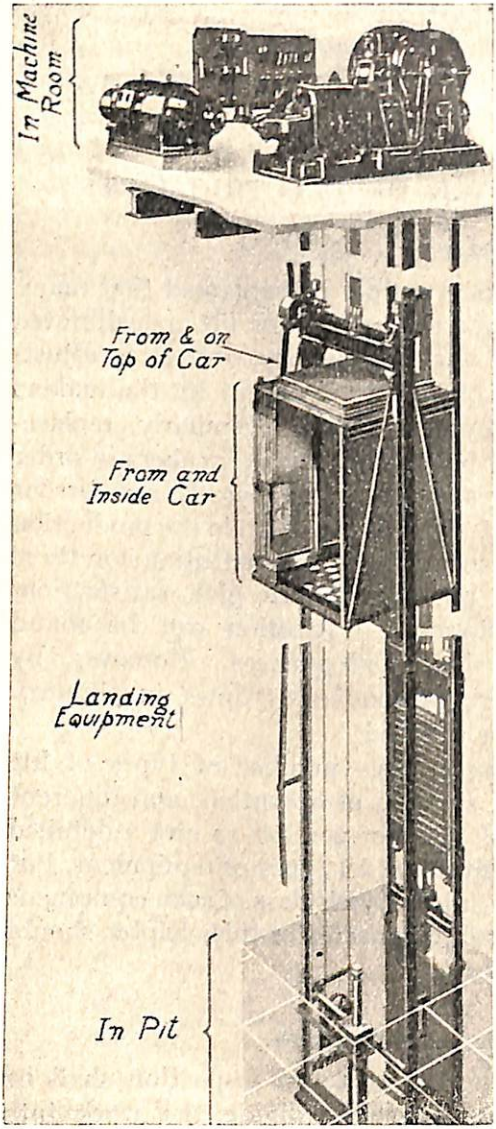
### Replacement of Parts.

AT this juncture it should be explained that many components of a modern electric lift are calibrated and set in the lift maker's factory, and such adjustments should not be disturbed except by the makers or an equally competent person. Similarly, replacement parts should be supplied by the makers in order that the advantages of special-alloy steels, non-ferrous alloys, and like materials that are used in the production of lift equipment are not lost; substitution for these materials cannot be expected to give satisfaction, and in some instances substitution can be found responsible for serious consequences. Moreover, by replacing worn parts at convenient times, involuntary breakdowns can be avoided.

Owing to the very large number of types of lift machines, motors, systems of operation, and different methods of control, it is not possible to give a detailed description of maintaining all types of equipment, but as the general principles of each class of such equipment are the same, the subject-matter of this chapter should be generally applicable.

### A Suitable Maintenance Routine.

In order that the procedure of inspection shall be systematic it is advisable to divide the work into




several categories, and the following routine can no doubt be varied to suit particular requirements.

Needless to say, those engaged on inspection duty should be alert at all times to avoid being injured by moving equipment; when standing in the lift pit special care should be taken to stand clear of the counterweight, and when a person

FIG. 90. TYPICAL LIFT INSTALLATION WITH GEARED MACHINE AND VARIABLE-VOLTAGE CONTROL. This shows the classification of maintenance routine.

is in the lift pit it is advisable for the car to be stopped at not less than 7 ft. 6 in. from the floor of the pit. Similarly, when working on the top of the car, great care should be taken to avoid any overhead steelwork, diverting pulleys, or the like obstructions. Before an examination of any electrical equipment is made the main switch should be opened.

## LANDING EQUIPMENT

With present-day lifts having solid enclosures the landing equipment usually comprises the landing doors or gates and the call pushes for calling the car with automatically operated lifts, or for actuating the call indicator in the car with attendant-operated lifts, but with lifts having wrought-iron and grille enclosures it is also necessary to note whether all wire panels are properly fixed.

**Landing Doors and Gates.**

Each landing door or gate should be examined for damage and any broken vision panels in the doors should be replaced. Whilst the inspection and cleaning of the gates and doors are easily carried out from the car, it is convenient to ensure that the gates or doors cannot be forced out of their tracks from the landing. An attempt should be made to open the door or gate in the normal manner and also by lifting it while the car is at another floor to ensure that the mechanical portion of the landing locking device is functioning correctly.

**Landing Pushes.**

Call pushes on automatically operated lifts can be checked by calling a car to each landing and call

pushes on attendant-operated lifts can be tested by noting the corresponding signals in the call indicator in the car. With battery-operated call indicators any sluggishness in the operation of all of the call-indicator movements is generally indicative of the battery becoming exhausted. After opening the main switch the contacts of the call pushes should be cleaned and the connections tested for being secure.

**Landing Indicators.**

Position indicators of either the illuminated or mechanical type are sometimes installed at the landings, and if they are of the former type any burned-out lamps should be renewed and broken screens replaced. The bearings of the pointer shaft of mechanical position indicators require lubricating occasionally. The renewal of lamps also becomes necessary from time to time in "direction," "car-coming," and similar indicators.

## MAINTENANCE FROM INSIDE CAR

**Landing-door and Gate Devices.**

The lift-well equipment is examined from both the inside and the top of the car. From the inside of the car each landing door or gate can in turn be opened and closed to ascertain whether it runs freely and that tracks, rollers, door hangers, and the like are not worn or damaged; both top and bottom tracks and rollers should be cleaned and lubricated where necessary. When sliding doors are provided with automatic closers of a type as shown in Fig. 91, the spring tension should be sufficient to close the door properly without

undue force and the oil level should, if necessary, be restored in door-closer dashpots. All bearing points in door-closing equipment should be examined for wear. As explained in Chapter IV, page 123, some sliding doors are provided with a pawl-and-rack device at the lower edge of the moving panel to ensure that the door cannot be reopened from the landing side after the lock contact has just closed. The correct functioning of this secondary locking device is important, and it can be checked by allowing the door almost to close but not lock; in reopening it, the door should not open more than 4 in., being prevented from opening farther by the pawl, as shown in Fig. 92.

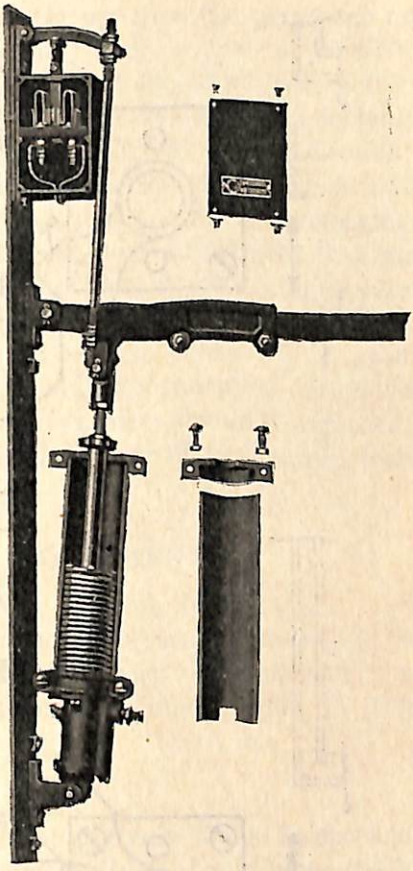


FIG. 91.—CLOSING DEVICE AND CONTACT FOR SLIDING DOORS.
The oil dashpot check is arranged below the spring housing.

Each landing-door or gate-lock contact can be

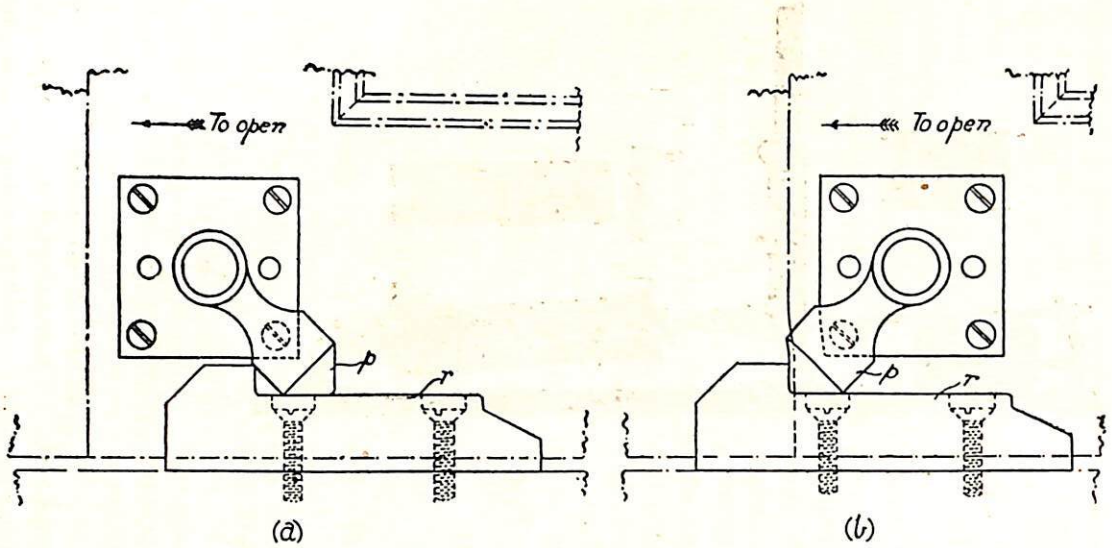



FIG. 92.—SECONDARY LOCK ON SLIDING DOORS.

(*a*) Pawl (*p*) passes over stop on rack (*r*) when door is opened from fully closed position.

(*b*) Pawl (*p*) engages with stop on rack (*r*) when door is opened from almost closed position, i.e. after contact has closed.

tested by trying to start the car from the car switch or car buttons with the landing door or gate open. With any landing door or gate open it should not be possible to start the car. The contacts in locks and locking devices should be examined for wear and cleaned; any springs used in the construction of the lock should be examined for fatigue. Whilst such locks and locking devices are generally robust their adjustment is often critical, and no attempt should be made to compensate for wear by filing various parts; other makeshifts are also to be condemned, because locks are a most important safety device, and misadjustment may have serious consequences. Worn parts should be replaced, and even the entire replacement of a damaged lock may be warranted.

## CAR EQUIPMENT

Having examined the landing doors, gates, and locking devices from inside the car, attention can be paid to the car equipment before commencing the inspection of the lift-well equpiment from the top of the car.

**Car Door or Gate.**

The car door or gate and its tracks should be checked for damage and wear, and whilst it should move freely it must not be possible for it to come out of its track. After the gate members and tracks have been cleaned the various rollers and fulcrums should be lubricated, but care should be taken to avoid any oil remaining on the gate members that may soil clothing.

With any lift car that is not provided with a movable car floor it should not be possible to operate the lift

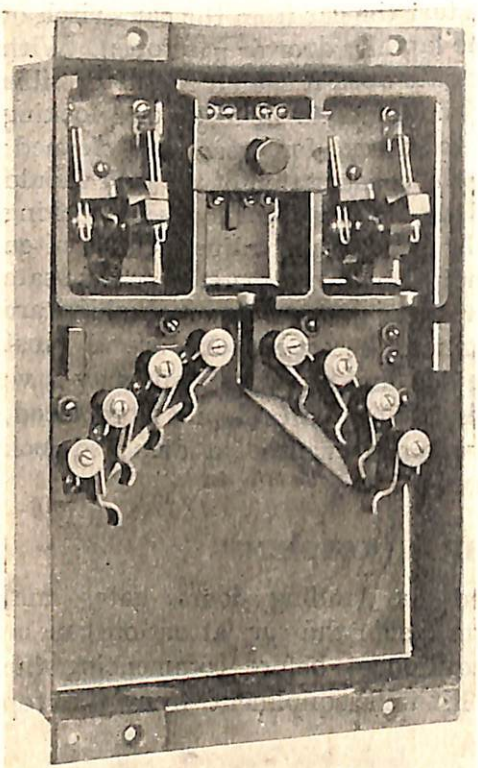


FIG. 93.—CAR SWITCH WITH COVER REMOVED. The auxiliary switches and stationary contacts are readily accessible when cover has been removed.

in any circumstances with the car gate open. Automatically operated lifts with movable car floors can, however, be called to a floor with a car gate open provided the car is unoccupied. To test the car-gate contact all landing doors or gates should be closed and the car switch handle moved or a car button pressed, and the car should not start if the car gate is open. The car-gate contacts should be examined for wear, cleaned, and pivot pins lubricated.

**Car-operating Devices.**

The car-operating device, which may consist of a car switch or a set of push-buttons, should then receive attention. Car-switch handles are of the self-centring

type, and if the return spring becomes weak or broken it should be replaced. Contacts should be examined after the main switch has been opened, and cleaned, but renewed if necessary, and the fulcrum of the car-switch handle should be lubricated. The above remarks regarding springs and contacts are equally applicable to push-buttons, and each button should be pressed to ensure that it returns to its normal position when released. The "stop" push or safety switch and any alarm push and car indicators should also be tested to determine whether they operate properly.

**Movable Car Floors.**

Some automatically operated lifts are provided with movable car floors, the construction of which varies considerably, but care should be taken to see that the floor and its switch function correctly. With some types of floors it is possible to raise the platform when standing at a landing and then remove any accumulation of dirt and lubricate all moving parts. With other types of floors it is necessary to release the stops when standing in the pit before the platform can be raised. After ensuring that the platform is free from undue friction, the floor switch should be examined to determine whether the contacts are making and breaking properly. The contacts should be cleaned, any springs tested for tension, and connections to contacts made secure if loose. It should be remembered that the weight of even a child should be sufficient to depress the floor and actuate the switch.

Whilst the majority of lift cars are soundly constructed, it is advisable to ascertain whether all panels

are securely fixed and not broken. Some goods lifts have timber floors, which become worn with the moving in and out of heavy loads, and when the wear is excessive the floor should be renewed. Similarly, passenger-car floors are usually covered with linoleum or similar material, and worn floor covering should be renewed before it becomes a source of danger. Before leaving the car the car-light fittings should be examined for breakages and secure fixing. A poorly illuminated car is false economy, and old lamps or low-powered ones should be replaced by new or higher-power lamps.

Having completed the necessary maintenance work of the car and car equipment, it is advisable to drive the car up and down the lift well and note the stopping performance at extremes of travel, if two speeds are available, observe that proper slowing takes place. Note the effect of the brake when stopping and that the rates of acceleration and retardation are satisfactory, so that any necessary adjustment can be made when examining the machine-room equipment.

## MAINTENANCE FROM TOP OF CAR

The next step is to examine lift-well equipment from the top of the car. By instructing the assistant inspector to lower the car a few feet and then opening the landing door or gate by use of the emergency key or by other suitable means, it is possible to gain easy access to the top of the car. Having made sure of being in a safe position relative to the overhead supporting steelwork, pulleys, and similar projections, the landing door can be reclosed and the assistant told to proceed towards the top of the lift well until instructed to stop in order that the limit switches may be

examined. It is, of course, understood that the assistant inspector is alert and carries out the inspector's instructions regarding the driving of the car promptly and correctly, especially when a person is standing on top of the car and is approaching the top floor.

**Limit Switches.**

As explained in Chapter IV, page 113, it is usual to install two limit switches near the top and bottom of the lift well for single-speed lifts and three limit switches for 2-speed lifts. The examination of any multiple-contact stopping switch, or other limit switches, mounted on the car frame for actuation by cams fitted in the lift well will naturally take the place of that for any slowing and stopping limit switches fitted in the lift well, but the final or overtravel limit switches will be found mounted in the lift well. By instructing the assistant to stop the car when the upper overtravel limit switch can just be reached by hand it is possible to open the switch manually; and when open, the assistant should attempt to drive the car in either direction. The opening of an overtravel limit switch should prevent travel in either direction. The lower limit switches for stopping and slowing should, if accessible after the car has been lowered, then be examined in a similar manner. If they are not accessible from the top of the car, this work can be done from the pit.

It is advisable to ensure that all limit switches and their associated cams are securely fixed; contacts in limit and stopping switches should be examined and cleaned, and the connections to them should be secure.

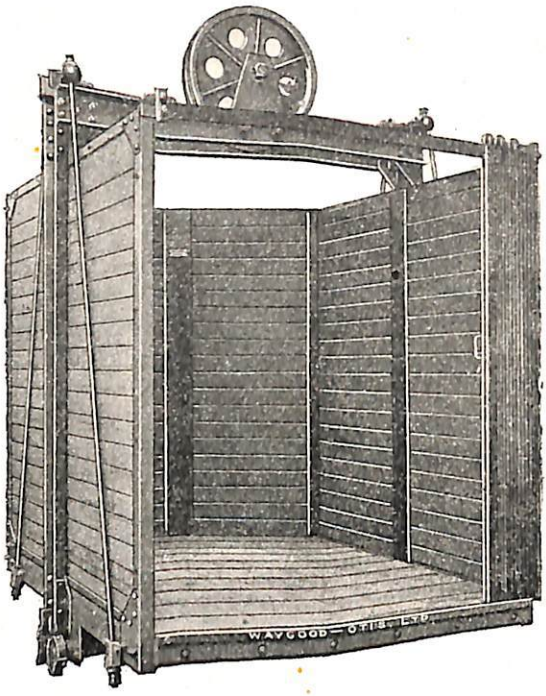


FIG. 94.—GOODS LIFT CAR.
This is fitted with a cam type of safety. The 2:1 pulley is carried on the cross-head.

These switches should be tested by hand to determine whether the return and contact springs have become fatigued. All pivot points should be lubricated and worn parts renewed.

While on the top of the car, any switches used for levelling purposes should also be examined, cleaned, and lubricated in a similar manner to those described above.

**Landing and Car-door Operators.**

Some cars are equipped with door operators, which should also be checked for proper operation by instructing the assistant to operate the necessary controlling switches or pushes in the car. After cleaning the door-operating mechanism and lubricating the various items, the door limit switches should be examined and the bearings of the motor and its associated equipment checked for wear.

Retiring-cam devices, as explained in Chapter IV, page 124, are sometimes used in conjunction with the landing-door locking devices, and they are mounted on the car frame. Most retiring-cam devices are furnished with a dashpot to prevent slamming, and the action of the dashpot should, if necessary, be re-adjusted to give the desired action. The mechanical connections between the retiring cam and its operating device should be lubricated, and adjustment can be made for normal wear.

**Lifting Ropes and Rope Anchorages.**

Having completed the maintenance work of the various electrical devices on the car, attention can be paid to the other equipment in the lift well. Several methods of attaching the lifting ropes to the car frame and counterweight are employed, but metalled sockets and splicing are usually found. Commencing with the rope anchorages on the car, the ropes should be examined for broken wires or displaced strands. The car should then be moved until the counterweight is opposite the car, so that a similar inspection can be made of the rope anchorages on the counterweight. With the counterweight in this position it is possible

to check the tightness of all nuts used on the counterweight and note any wearing of the guide shoes. If an oil buffer is fitted to the counterweight the oil-level should be checked by opening the pet cock or removing the plug. Care should be taken when adding oil to the buffer that the same grade of oil as the original is used. When a lift is roped 2 : 1, the bearing of the 2 : 1 pulley on the car (Fig. 94) and counterweight should be examined for wear and lubricated. Similarly, when overhead or diverting pulleys are more easily accessible on the top of the car, they should be lubricated and examined for wear whilst the inspection is being made from the top of the car.

By instructing the assistant to raise the car, say, 2 ft. at a time, it is possible to wipe the ropes free from fluff and examine them, commencing at the counterweight anchorages. Flattened strands, due to wear, and broken wires should be noted especially for badly worn sections and a number of adjacent wires with breaks, because a rope which may appear sound except for even a section is not reliable. Ropes as a rule give a good indication of their condition before renewal is necessary, but with service under some abnormal conditions they may become dry and break up internally. The importance of a conscientious examination of ropes cannot be overstressed, and owing to the many types of ropes now in use it is difficult to give precise data regarding the condition of a rope when it should be discarded. As the allowable number of broken wires in one lay or adjacent wires in any one strand can vary with the rope construction, experience becomes the best guide in deciding whether to allow a rope to continue in service or to condemn it.

The fibre cores of ropes are impregnated with a lubricating compound during rope manufacture, and this supply of lubricant is often sufficient for the life of the rope; but in some instances where the rope appears to be dry, lubrication is advisable. The object in lubricating the ropes should be to replenish the supply of lubricant in the cores and for it to remain in the interstices of the rope. For this purpose suitable wire-rope lubricants have been developed. With traction-drive machines, however, care should be taken that the lubricant does not cause slipping of the rope in the traction sheave; in fact, a rust-preventing preparation can be used to advantage on ropes used with traction machines.

**Rope Tension.**

An important factor in the life of a set of ropes is that each rope carries its proper share of the load. The tension in each rope should therefore be checked periodically by means of a spring balance. By hooking the spring balance to one of the ropes and pulling it horizontally, the deflection and reading are noted. This is repeated for each of the remaining ropes, and if any rope gives a greater deflection than the others for the same reading it is necessary to tighten the nuts on the eyebolts or rope thimbles until equal deflection is attained. In no circumstances should eyebolts or rope thimbles be rotated, because this upsets the construction of the rope.

**Governor and Safety Ropes.**

The majority of car-safety mechanisms are operated by a governor or a safety rope, as described in Chapter

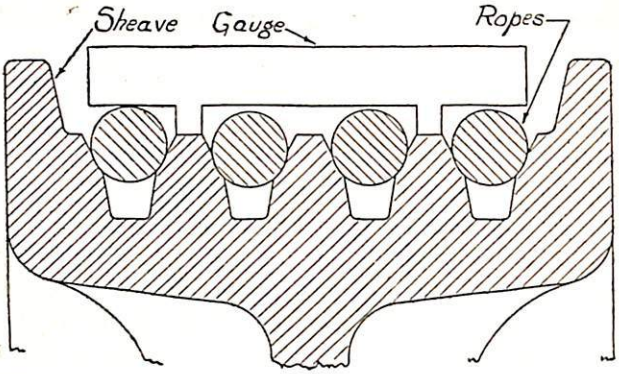



FIG. 95.—GAUGE TO INDICATE GROOVE WEAR IN SHEAVE. Distances between tops of ropes and gauge indicate extent of any wear.

IV, page 133, and the governor rope or safety rope can be examined and cleaned at the same time as the lifting ropes are being inspected. With high-speed lifts the governor rope is attached to a shackle held by a releasing device carried from the car frame. The tension of the spring which causes the releasing carrier to hold the shackle should be sufficient to retain the shackle during normal operation, but not sufficient to cause the governor rope to slip in the governor jaws.

**Flexible Cables.**

While on the car it is convenient to examine the flexible cables and ascertain that their fastenings at the lift-well terminal box are secure. By instructing the assistant inspector to lower the car in stages of, say, 2 ft., the covering of the cables can be inspected for wear or damage. The remaining part of these cables and their fastenings at the car terminal box can be examined from the pit.

**Guides.**

Before leaving the top of the car the guides for the car and counterweight should be cleaned and oiled. Sometimes guide lubricators are fitted to the top of the guides or to the guide shoes, and these should be filled with oil and the rate of flow adjusted if necessary. All joints in guides should be examined and care taken to ensure that the fixing brackets are securely attached to the guides and also to the sides of the lift well or equivalent supports. The guide shoes on the top of the car frame should be examined for wear.

## MAINTENANCE WORK IN THE PIT

By raising the car about 6 ft. above the lowest floor and opening the landing door or gate by means of the emergency key or the like, it is possible to gain admittance to the pit; with deep pits the use of a

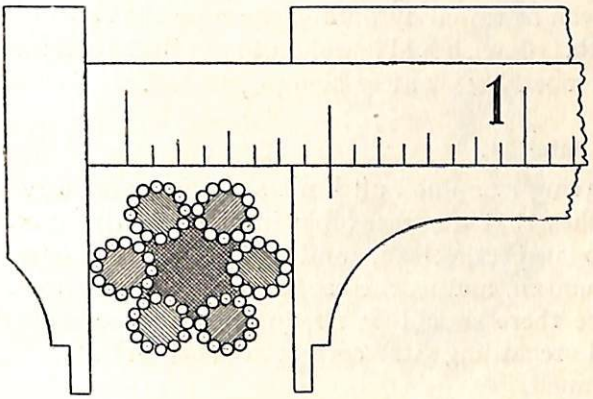



FIG. 96.—CORRECT METHOD OF MEASURING ROPE DIAMETER.

The diameter of a rope is the diameter of the circle described about it.

ladder is an advantage. The floor of the pit should be cleaned and any accumulation of oil or dirt removed.

**Limit Switches.**

The lower overtravel limit switch can be tested by instructing the assistant to raise the car, and while the car is in motion this switch can be opened and the car should stop. While the switch is open the assistant should be instructed to attempt to lower the car to ensure that the opening of the overtravel limit switch prevents movement in both directions. In the unlikely event of the car moving during this test the assistant should switch off immediately. Maintenance work on this switch and also on any other limit switches that have not already been examined should then be carried out in a similar manner to that with the upper limit switches. Main-line limit final switches, actuated by an endless rope as described in Chapter IV, page 114, can be tested by pulling the rope that actuates the switch. Care should be taken to see that such switches are properly reset after being operated.

**Car Safeties.**

Having examined all limit switches, and any other switches that are accessible in the pit, the next step is to inspect, clean, and lubricate the car-safety mechanism, and as the car safety is a most important device there should be no question in the inspector's mind regarding its correct operation after being examined.

With instantaneous type safeties as described in Chapter IV, page 133, the tripping rods (*c*) should lift simultaneously, so that the rollers (*a*) grip the

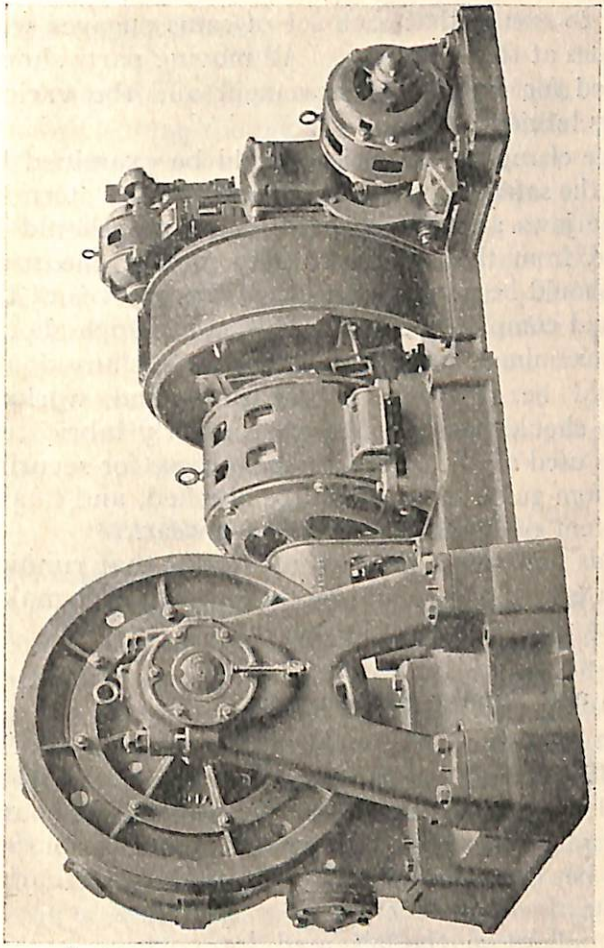


FIG. 97.—SELF-LEVELLING TRACTION MACHINE FOR A.C.
Guard removed for maintenance work should be replaced and securely fastened.

guides at the same time. Similarly, with cam operated safeties as shown in Fig. 94, the camshafts should be rotated to ensure that each set of cams engages with the guides at the same time. All moving parts should be tested for freedom of movement and the various bearings lubricated.

Wedge-clamp type safeties should be examined by pulling the safety rope to rotate the drum to determine that the jaws grip the guides. The drum should be rewound from the car in order to replace the rope, which should be properly wound in the grooves of the drum and completely fill it. This safety rope should also be examined, and if its condition raises any doubt it should be renewed. All bearings and working surfaces should be quite free and properly lubricated. All nuts used on the safety and also those for securing the bottom guide shoes should be checked, and finally the bottom guide shoes examined for wear.

At this juncture it may be mentioned that running tests on car safeties should be made by the lift maker and with the consent of the owner.

**Buffers and Sundry Equipment.**

When oil buffers are installed, the plunger of the car buffer should be depressed by hand and then released to ensure that it returns automatically, and if necessary the oil-level restored. Spring buffers should be examined for damage and for security of fixing.

Any pulleys in the pit used for governor ropes, compensating ropes, or the like should be cleaned and checked for worn bearings and lubricators refilled.

As previously explained, that part of the flexible

cable that cannot be examined from the top of the car should now be inspected, and also its fastening to the car terminal box.

**Top Clearance of Car and Counter-weight.**

Before leaving the pit, the length of the lifting ropes can be checked by instructing the assistant to drive the car to the top floor and note the clearance between the bottom of the counterweight, or its oil buffer and the striking block. The length of the ropes should be such that the clearance between the car and overhead projection when the counterweight buffer is fully compressed is as great as practicable. Similarly, when the car buffer is fully compressed, the top of the counterweight should clear any overhead projections by a reasonable distance.

## MACHINE-ROOM EQUIPMENT

**Lift Machines.**

Commencing with the lift machine, first wipe away all surplus oil and dirt and replenish all oil and grease reservoirs. It may be mentioned here parenthetically that old grease should be removed from grease cups and old oil drained from lubricators and also from the gearbox at proper intervals and replaced with fresh lubricant, because all lubricants gradually lose their lubricating properties in use. It is also important that the correct grade of lubricant is used, as the mixing of unsuitable oils can cause serious trouble.

Before any dismantling of the machine is carried out the counterweight should be landed on its buffer; this precaution will prevent accidents caused by the counterweight running away.

When keys are used to secure the wormwheel and drum or traction sheave to the mainshaft, such keys should be inspected to ensure that these parts have not worked loose. Particular attention should be paid to the diameter of the rope grooves in traction sheaves, because grooves of unequal diameter can be a contributory factor in excessive rope wear. These diameters can be checked by means of a suitable guage placed across the ropes, as shown in Fig. 95, and any variation in the distances between the guage and the top of the ropes will indicate unequal wearing of the grooves. When the grooves are such that the tops of the ropes lie below the tops of the grooves, an ordinary straight-edge can be used in place of the gauge. If the ropes vary in diameter and are due for renewal, a set of circular rods or gauges of the same diameter as the new rope can be laid in the grooves for checking purposes. It should be remembered that the diameter of the rope is the diameter of the circle described about it, and is therefore measured as shown in Fig. 96. In most instances the original sheaves have sufficient metal to allow worn grooves to be regrooved in a lathe.

That part of the rope which could not be inspected in the lift well can now be examined in the machine-room.

The worm and wormwheel should be inspected for excessive wear causing backlash and endplay of the worm; inspection covers are usually provided to facilitate inspection of gear members. Backlash is the amount of play between the wormwheel teeth and the worm thread; endplay is the amount of lateral movement of the worm. For smooth running both

backlash and endplay should be as small as possible. Whilst it is often possible to reduce endplay by adjusting the thrust unit, excessive backlash is the result of wear. The bearing of the machine should be examined for wear, and as, according to the type of machine, excessive wear on the main bearings can produce undue backlash or alternatively a complete absence of it, inasmuch that the worm will be subjected to excessive load resulting from the deep meshing of the wormwheel, worn bearings should therefore be replaced before the conditions just cited can arise.

**Motors.**

Before inspecting any electrical equipment, the main switch should be opened. The inspection of the motor will vary according to its type. The most trouble-free type of motor is the high-torque squirrel-cage, which has neither commutator, slip-rings, nor brushes; nevertheless its windings should be kept free from an accumulation of dust and oil. Wearing of bearings can be checked by testing the air gap between the rotor and stator with a suitable feeler gauge. Commutators should be cleaned and any high micas between the segments undercut and worn brushes replaced.

**Brakes.**

As explained in Chapter III, page 79, many types of electro-mechanical brakes are employed on lift machines, but the spring tension for applying the brake shoes should be so adjusted that the car stops without jolt or slide. Brake linings should be examined for wear and renewed before the rivet heads touch

the brake drum. The clearance between the brake linings and the brake drum should be just sufficient to ensure that the linings clear the drum. All fulcrum points should be lubricated, and with oil-immersed brakes the oil-level should, if necessary, be restored by adding the correct kind of oil.

**Faults.**

It will be appreciated that after a lift has been put into service and has operated satisfactorily, the majority of faults are due to wear, and routine maintenance will therefore obviate such faults. Mechanical faults are often accompanied by undue noise, and the remedy is usually self-evident. Electrical faults can often be traced to faulty contacts, wear, or loose or broken connections, and the nature of the fault is indicative of its position. It should be remembered that obscure faults are the exception and not the rule, and that the most obvious faults can be overlooked if the examination of the equipment is made in a cursory manner. The process of finding a fault should therefore be systematic, commencing with, say, the operating fuse and examining each part of the equipment in the circuit under suspicion. The position of an "earth" fault can be found by isolating the circuits in which the fault is likely to be, and, by means of a Megger testing set, each of these circuits can be tested and thus by a process of elimination the faulty component can be found. With some automatic equipment, however, experience and a thorough knowledge of the equipment are necessary to locate a fault quickly.

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